The Effects of Hatchery Effluents On Water Chemistry, Periphyton and Benthic Invertebrates of Selected British Columbia Streams

K.A. Munro, S.C. Samis and M.D. Nassichuk

Habitat Management Division
Field Services Branch
Department of Fisheries and Oceans
1090 West Pender Street
Vancouver, B.C. V6E 2P1

June, 1985

Canadian Manuscript Report of
Fisheries and Aquatic Sciences
No. 1830

85-5845/

Canadian Manuscript Report of Fisheries and Aquatic Sciences

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Canadian Manuscript Report of
Fisheries and Aquatic Sciences 1830

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THE EFFECTS OF HATCHERY EFFLUENTS ON WATER CHEMISTRY, PERIPHYTON AND BENTHIC INVERTEBRATES OF SELECTED BRITISH COLUMBIA STREAMS

by

K.A. Munro, S.C. Samis and M.D. Nassichuk
Habitat Management Division
Field Services Branch
Department of Fisheries and Oceans
1090 West Pender Street
Vancouver, B.C.
V6E 2P1

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Cat. No. Fs 97-6/1830 E   ISSN 0706-6473

Correct citation for this publication:

Munro, K.A., S.C. Samis and M.D. Nassichuk. 1985. The effects of hatchery effluents on water chemistry, periphyton and benthic invertebrates of selected British Columbia streams. Can. MS Rep. Fish. Aquat. Sci. 1830: xvii + 203 p.

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ABSTRACT

Munro, K.A., S.C. Samis and M.D. Nassichuk. 1985. The effects of hatchery effluents on water chemistry, periphyton and benthic invertebrates of selected British Columbia streams. Can. MS Rep. Fish. Aquat. Sci. 1830: xvii + 203 p.

The effects of effluents from selected British Columbia salmon hatcheries on receiving water quality, periphyton, and benthic invertebrates were studied from 1978 to 1981. Elevated concentrations of total phosphate and ammonia were recorded in streams downstream of effluent discharges. Higher periphyton chlorophyll *a* and organic weight accumulations on artificial and natural substrates and greater abundance of benthic invertebrates were found in streams immediately downstream of effluent discharges than in upstream areas. Changes in benthic communities usually were restricted to areas 60 to 700 m downstream of effluent discharges and reflected nutrient enrichment rather than degradation of habitats in most streams.

Species composition of the periphyton differed in areas upstream and downstream of hatchery discharges. The green algae *Ulothrix zonata* and *U. tenuissima* were abundant in most streams, particularly immediately downstream of the discharges. The diatom *Achnanthes minutissima* was predominant in most streams. However, diatoms more typical of nutrient-rich conditions, such as *Nitzschia palea*, *Ni*. cf. *fonticola*, and *Navicula pelliculosa*, were abundant in downstream areas. Chironomidae (Diptera) were the most abundant benthic invertebrates in most streams, and, along with Naididae (Oligochaeta) in some streams, were more abundant downstream of effluent discharges than upstream.

The response of benthic communities to hatchery discharges was affected by the size of hatchery and the quantity of phosphate and ammonia in the effluent. The levels of nutrients, periphyton, and benthic invertebrates present upstream of the hatchery discharges also influenced the response of the benthos to effluent discharges. The streams with the highest natural productivity responded most strongly to effluent addition.

Key words: Hatchery discharges, streams, ammonia, phosphate, periphyton, benthic invertebrates

RÉSUMÉ

Munro, K.A., S.C. Samis and M.D. Nassichuk. 1985. The effects of hatchery effluents on water chemistry, periphyton and benthic invertebrates of selected British Columbia stream. Can. MS Rep. Fish. Aquat. Sci. 1830: xvii + 203 p.

On a étudié de 1978 à 1981 les effets des effluents provenant de certaines piscifactures de saumon de la Colombie-Britannique sur la qualité, le périphyton et less invertébrés benthiques des eaux qui les reçoivent. On a enregistré des concertrations élevées de phosphate total et d'ammoniac dans les cours d'eau situés en aval de l'endroit où se déversent les effluents. On a trouveé que la teneur en chlorophylle a du priphyton et l'accumulation de matiére organique sur les substrats naturels et artificiels étaient plus élevés dans les cours d'eau situés immédiatement en aval de l'endroit de rejet des effluents que dans les seceurs situés en amont et que les invertébrés benthiques y étaient plus abondants. Les changements dans les communautés d'organismes benthiques étaient habituellement limités, dans la plupart des cours d'eau, aux seceurs situés entre 60 et 700 m en aval de l'endroit de rejet des effluents et correspondaient plutôt à un enrichissement du cours d'eau en substances nutritives qu'à une dégradation de l'habitat.

La composition des espéces constituant le priphyton était différente dans les secteurs situés en aval et en amont de l'endroit des rejects des piscifactures. Les algues vertes *Ulothrix zonata* et *U. tenuissima* étaient abondantes dans la plupart des cours d'eau, surtout immédiatement en aval de l'endroit des rejets. Dans la plupart des cours d'eau, c'est la diatomée *Achnanthes minutissima* qui se retrouvait en plus grande abondance. Cependant, les diatomées plus caractéristiques des milieux riches en substances nutritives, comme *Nitzschia palea*, *Ni.* cf. *fonticola* et *Navicula pelliculosa*, étaient abondantes dans les secteurs situés en aval. Les chironomidés (diptéres) étaient les invertébrés benthiques les plus nombreux dans la plupart des cours d'eau et, comme les Naididés (Oligochétes) dans certains cours d'eau et, comme les Naididés (Oligochétes) dans certains cours d'eau ils étaient plus abondants en aval de l'endroit de rejet des effluents qu'en amont.

La taille de la piscifacture et la quantité de phosphate et d'ammoniac présents dans l'effluent sont deux facteures qui ont influé sur la réaction des communautés d'organismes benthiques aux rejects des piscifactures. Les quantités de substances nutritives, de périphyton et d'invertébrés benthiques présents en

RÉSUMÉ

amont de l'endroit de rejet des piscifactures ont également influé sur la réaction du benthos aux rejcts d'effluents. Ce sont les cours d'eau ayant la productivité naturelle la plus élevée qui ont réagi le plus fortement à l'ajout d'effluents.

Mot-clés: rejets des piscifactures, cours d'eau, ammoniac, phosphate, périphyton, invertébrés benthiques.

INTRODUCTION

Many hatcheries have been built in British Columbia as part of the Salmonid Enhancement Program (SEP). With the increased hatchery production, concerns were expressed about possible effects of hatchery effluents on the aquatic environments of those streams into which the effluents were discharged. The ability of conventional wastewater treatment technologies to adequately treat hatchery effluents also was of concern. In response to these issues, a study was made of the chemical characteristics of hatchery effluents from selected B.C. hatcheries (Underwood McLellan Ltd. 1979a). A second study assessed the effectiveness of effluent treatment methods (Underwood McLellan Ltd. 1979b). In this report, we present the results of a study on the environmental effects of hatchery effluent discharges on several B.C. streams.

The chemical composition of hatchery effluents has been described by Nakatani et al. (1973) and Underwood McLellan Ltd. (1979a). However, the effects of hatchery discharges on receiving waters have not been studied thoroughly. Increased concentrations of phosphate and ammonia; increased accumulations of benthic algae; and changes in species composition of periphyton (including algae, bacteria, fungi, and protozoa) have been reported downstream of fish hatchery discharges (Liao and Mayo 1970; Nakatani et al. 1973; Ball and Kevern 1973; Bahls and Bahls 1974). Although nutrient enrichment may benefit nutrient poor streams, the discharge of high levels of nitrogen and phosphorus may result in the degradation of receiving waters through decreases in dissolved oxygen levels, the development of nuisance levels of periphyton and modification of benthic invertebrate communities (Nakatani et al. 1973).

The present study examined a number of B.C. coastal streams which receive hatchery effluents and several interior streams where hatcheries have been proposed. Water chemistry and the abundance and composition of the periphyton and benthic invertebrates were studied during spring fish rearing periods or throughout the year to assess the extent and seasonality of the effects of hatchery discharges on receiving waters. The relationships between hatchery operations and environmental changes in the streams also were examined to assess the appropriateness of provincial hatchery effluent guidelines for SEP salmon rearing facilities.

STUDY AREAS

Several British Columbia streams with existing or proposed hatchery operations were sampled (Fig. 1). Hydrographic data for these streams and fish rearing information for the hatcheries studied are presented in Table 1.

QUINSAM RIVER

The Quinsam River is a tributary of the Campbell River on the east coast of Vancouver Island. Flows are regulated by B.C. Hydro at a dam on Wokas Lake. The Quinsam Hatchery is located on the Quinsam River, 3.25 km upstream of its confluence with the Campbell River. Water used for fish rearing is taken from Cold Creek and the Quinsam River. Fish are reared year-round in aluminum troughs, circular tubs and concrete rectangular ponds (Burrows ponds). Effluent passes through two clarifiers to reduce the amount of suspended solids prior to discharge into the Quinsam River. Hatchery influent and effluent waters were sampled for chemical analyses concurrent with river sampling.

Water, periphyton, and benthic invertebrates were sampled at four sites in the Quinsam River (Fig. 2a, 3). Site 1, the control site, was established 350 m upstream of the hatchery discharge and sites 2, 3, and 4 were 60, 300, and 1800 m respectively, downstream of the discharge. The river substrate was comprised mainly of boulders and cobbles. Light penetration to the river channel was restricted by trees in places, with site 4 the least shaded and site 2 the most shaded site.

PUNTLEDGE RIVER

The Puntledge River is a tributary of the Courtenay River on the east coast of Vancouver Island. Flows are regulated by B.C. Hydro at a dam on Comox Lake, 10.4 km upstream of the confluence of the Puntledge and Tsolum Rivers. The Puntledge Hatchery (upper site) is located adjacent to a B.C. Hydro impoundment. Occasionally, water in excess of power generation requirements is released to the river. Fish are reared year-round in gravel channels and Burrows ponds using Puntledge River water, and effluent is discharged untreated to the river. Hatchery influent and effluent waters were sampled for chemical analyses concurrent with river sampling. An additional hatchery (lower site) was constructed in 1981, seven kilometres downstream of the upper hatchery, but was not studied.

Water, periphyton, and benthic invertebrates were sampled at three sites in the Puntledge River and at a control site (site 1) within the hatchery (Fig. 2b, 3). Site 1 was located at the upper end of the hatchery spawning channel because hatchery effluent was discharged immediately downstream of the impounding weir, upstream of which there was no suitable sampling site. Sites 2, 3, and 4 were located 120, 700, and 1350 m respectively, downstream of the hatchery discharge. Puntledge River substrate was comprised mainly of sandstone bedrock, with small areas of boulders, cobbles and gravel. The spawning channel substrate at site 1 was comprised of cobbles and gravel. The broad river channel permitted substantial exposure to sunlight, except at site 4.

BIG QUALICUM RIVER

The Big Qualicum River, on the east coast of Vancouver Island, flows into the Strait of Georgia. River flows are regulated by a dam on Horne Lake which is controlled by the Department of Fisheries and Oceans. The Big Qualicum Hatchery (1.5 km upstream of the river mouth) and an experimental rearing channel (3.5 km upstream of the main hatchery) were studied. Fish are reared year-round using Big Qualicum River water; untreated hatchery effluents are discharged into the river. Effluents from the experimental rearing operation (a gravel channel) and the main hatchery (gravel rearing channels, concrete raceways and Burrows ponds) were sampled for chemical analyses concurrent with river sampling.

Water, periphyton and benthic invertebrates were sampled at six sites in the Big Qualicum River: an upstream control site, two sites downstream of the experimental rearing channel, and three sites downstream of the main hatchery (Fig. 2c, 3). Benthic invertebrates also were sampled downstream of the experimental rearing channel (site 2a) and immediately upstream of the main hatchery (site 3a). Site 1, the control site, was established 50 m upstream of the experimental rearing channel. Sites 2, 2a, and 3 were located 90, 1000, and 2000 m respectively, downstream of the experimental rearing channel discharge. Site 3 was considered a control site for periphyton and water sampling. Site 3a, used for benthic invertebrate sampling, was considered a control site with respect to the main hatchery discharge. Site 3a was located 3300 m downstream of the experimental rearing channel discharge and 200 m upstream of the main hatchery discharge. Sites 4, 5, and 6 were located 80, 280, and 600 m respectively, downstream of the main hatchery. The substrate of the Big Qualicum River was comprised largely of cobbles and sand. Light penetration to the river was substantial at most sites due to partial removal of trees.

CAPILANO RIVER

The Capilano River flows into Burrard Inlet, 5 km downstream of Cleveland Dam. The hatchery is located in the canyon section of the Capilano River, 300 m downstream of Cleveland Dam. River flows usually are very low in summer and high in winter, with frequent floods resulting from water release at the dam. Fish are reared year-round in aluminum troughs, concrete Burrows ponds, and earthen ponds using water from Capilano Lake. Untreated hatchery effluent is discharged into the Capilano River. Hatchery influent and effluent waters were sampled for chemical analyses concurrent with river sampling.

Water, periphyton, and benthic invertebrates were sampled at four sites in the Capilano River: three sites within the canyon section and one site downstream of it (Fig. 2d, 3). Site 1 was located 80 m upstream of the hatchery discharge and sites 2, 3, and 4 were located 60, 180, and 2300 m respectively, downstream. At site 2, the river water and effluent may not have been fully mixed; however, access was limited between sites 2 and 3. Capilano River substrate was comprised principally of large boulders. Light penetration was lower at sites 1, 2 and 3, within the canyon section, than at site 4, downstream of it.

CONUMA RIVER (TLUPANA HATCHERY)

The Conuma River flows into Tlupana Inlet, at the head of Nootka Sound on the west coast of Vancouver Island. Hydrographic data are not available for the study period, but the Conuma River is somewhat similar in size to the Big Qualicum River. Chum and chinook fry are reared in earthen channels during spring using groundwater and some surface water. Hatchery effluent is discharged untreated into Leagh Creek, at its confluence with the Conuma River. Hatchery influent, effluent and Leagh Creek waters were sampled for chemical analyses concurrent with Conuma River sampling.

Water, periphyton, and benthic invertebrates were sampled at four sites in the Conuma River (Fig. 2e). Site 1 was located 50 m upstream of the Leagh Creek confluence. Sites 2, 3, and 4 were located 50, 160, and 300 m respectively, downstream of the confluence, where the river was wider and less turbulent. The Conuma River substrate was comprised principally of cobbles. The sites were slightly shaded by trees.

INCHES CREEK

Inches Creek is a small, groundwater-fed tributary of Norrish Creek. Norrish Creek enters the Fraser River at Nicomen Slough near Mission. A pilot chum rearing facility was operated during spring 1979, where a rearing impoundment was constructed at the confluence of Inches and Barnes Creeks. A larger permanent facility subsequently was constructed several hundred meters upstream.

Water and periphyton were sampled in spring 1979 at four sites in Inches Creek and at one site in Barnes Creek (Fig. 2f). Site 1 was the control site in Barnes Creek and site 2 was the control site in Inches Creek, located 50 m upstream of the rearing impoundment. Site 2 was located in a deep, slow-flowing area of Inches Creek. Sites 3, 4, and 5 were located in Inches Creek, 30, 80, and 160 m respectively, downstream of the rearing impoundment, in riffle areas. The substrate of Inches and Barnes Creeks was comprised principally of cobbles, gravel and sand. The sites were well-exposed to sunlight during spring.

LOON CREEK

Loon Creek is a tributary of the Bonaparte River, which flows into the Thompson River. A provincial trout hatchery at Loon Creek was expanded to rear chinook fry in 1980. Fish were reared during spring in water from Loon Creek and a spring-fed tributary. Untreated effluent was discharged into the tributary during the 1980 study period. Subsequently, an effluent settling lagoon was constructed. Hatchery influent and effluent waters were sampled for chemical composition concurrent with stream sampling.

Water, periphyton, and benthic invertebrates were sampled at four sites in Loon Creek (Fig. 2g). Site 1, the control site, was located 20 m upstream of the hatchery effluent discharge; sites 2, 3, and 4 were 10, 150 and 275 m respectively, downstream of it. Loon Creek substrate was comprised principally of cobbles and boulders. All sites, except site 3, were well exposed to sunlight.

HIXON CREEK (INDIAN RIVER PILOT HATCHERY)

Hixon Creek is a tributary of the Indian River, which flows into Indian Arm, Burrard Inlet. A pilot hatchery was operated on Hixon Creek, using groundwater for rearing during spring. Untreated effluent was discharged into Hixon Creek. Hatchery influent, effluent, and Hixon Creek waters were sampled in May

1980. Water and periphyton were sampled in Hixon Creek 20 m upstream of the hatchery discharge and 25 m downstream of it. Hixon Creek substrate was comprised of coarse gravel.

BIRKENHEAD RIVER

The Birkenhead River is a tributary of the Lillooet River, which flows into Harrison Lake. The hatchery is located on the Birkenhead River, 3 km upstream of its confluence with the Lillooet River. In June 1979, periphyton were sampled in the Birkenhead River 20 m upstream of the hatchery discharge, 10 m downstream, and in the effluent channel.

SNOOTLI CREEK (BELLA COOLA HATCHERY)

Snootli Creek is a tributary of the Bella Coola River, on the B.C. central coast. Chum were reared using surface and groundwater during spring. Hatchery effluent was discharged into a tributary of Snootli Creek. Hatchery influent and effluent waters were sampled during the spring 1979 rearing period by SEP staff and hatchery study personnel. Periphyton were sampled in June 1979 in the tributary receiving the effluent and in Snootli Creek downstream of the confluence.

CHILLIWACK RIVER

The Chilliwack River is a tributary of the Fraser River. A major hatchery was constructed in 1980 at its confluence with Slesse Creek. From September 1978 to March 1980, water and periphyton were sampled in the Chilliwack River 100 m downstream of the confluence. The substrate was comprised principally of boulders and the site was well exposed to sunlight.

NICOLA RIVER

The Nicola River is a tributary of the Thompson River. During spring 1979, a groundwater-fed pilot rearing pond was operated at a site 8 km downstream of Merritt. Nicola River water and periphyton were sampled between September 1978 and October 1979, at a site 40 m downstream of the rearing pond outlet. The substrate was comprised principally of cobbles and the site was well exposed to sunlight.

DEADMAN RIVER

Deadman River, a Thompson River tributary, was considered for a hatchery in 1978. Deadman River is regulated by a dam on Snohoosh Lake. Water and periphyton were sampled 250 m downstream of Snohoosh Lake, in a shaded area with a boulder and cobble substrate.

EAGLE RIVER

The Eagle River is a tributary of the South Thompson River. A hatchery was built in 1983 downstream of the confluence of the Eagle River and Crazy Creek. Water chemistry and periphyton were sampled during spring and autumn 1980 in Crazy Creek (150 m upstream of the confluence) and in the Eagle River (500 m downstream of the confluence). Benthic invertebrates were sampled in the Eagle River. The Eagle River substrate was comprised of coarse gravel, whereas Crazy Creek substrate was largely cobble. Both sites were well exposed to sunlight.

FINN CREEK

Finn Creek, a tributary of the North Thompson River, was considered for hatchery development in 1980. Water, periphyton, and benthic invertebrates were sampled in Finn Creek 100 m upstream of the Highway #5 culvert. Finn Creek substrate was comprised principally of boulders and the area was well exposed to sunlight.

OTHER RIVERS

Water and periphyton were sampled in several other streams where hatcheries were proposed. Samples were taken on one occasion from a side channel of the Bowron River, and from the Cheakamus, Chehalis, Little Qualicum, Nitinat, Quesnel, Raft, and Stuart Rivers.

METHODS

Water and periphyton were sampled in streams between August 1978 and November 1980 (Table 2) during year-round hatchery operations (Quinsam, Puntledge, Big Qualicum, and Capilano Rivers); spring rearing operations (Conuma and Birkenhead Rivers, Inches, Loon, Snootli and Hixon Creeks); proposed rearing operations (Chilliwack, Nicola, Deadman and Eagle Rivers, and Finn Creek); and occasionally in other streams during surveys for potential hatchery development. Water and periphyton were sampled at three to six week intervals in streams where artificial substrates were used to measure periphyton accumulations (Table 2). Generally, a three week interval was used between spring and autumn and a six week interval during winter, depending on the amount of periphyton accumulation. In addition, effluents and receiving waters were sampled during cleaning of hatchery channels in late spring.

Benthic invertebrates were sampled in the Quinsam, Puntledge and Big Qualicum Rivers during the spring pre-emergence period (prior to the emergence of adult insects) and during the late summer maximum loading period (when hatchery feeding rates were high compared to river flows) (Table 3). The Puntledge and Big Qualicum Rivers also were sampled two weeks after the hatchery rearing channels were cleaned in early summer (the post-cleaning period). The Capilano River was sampled in late summer and the Conuma River, Eagle River, Loon Creek and Finn Creek were sampled during spring (Table 3).

WATER CHEMISTRY

The chemical composition of stream water and effluents was characterized through measurements of pH, alkalinity, turbidity, and concentrations of major cations, anions, and heavy metals. Nutrient concentrations (phosphorus, nitrate, ammonia, organic nitrogen and organic carbon) were measured to assess changes resulting from hatchery discharges. Parameters analyzed, analytical methods, and detection limits are listed in Table 4. The analytical methods were those described by Swingle and Davidson (1979). Samples were submitted within 24 hours of collection to the Environmental Protection Service/Department of Fisheries and Oceans (EPS/DFO) Chemistry Laboratory (West Vancouver, B.C.) for the analyses listed in Table 4, and the Inland Waters Directorate (IWD) Laboratory (North Vancouver, B.C.) for "low detection limit" analyses of nutrients in stream water.

Water was collected at midstream (0.1 to 0.3 m depth) in plastic or glass containers rinsed three times with stream water. Most samples were stored on ice in the field, then refrigerated at the laboratory until analyzed. Samples for extractable metals analyses were acidified in the field using concentrated nitric acid. Samples for mercury analysis were preserved using dilute nitric acid - dichromate reagent. Samples for dissolved oxygen (DO) analysis were preserved using the azide modification of the Winkler technique. Samples for biochemical oxygen demand (BOD) analysis were frozen, or stored at 4°C and analyzed within 48 hours of collection.

Samples for the analysis of particulate carbon (PC), particulate nitrogen (PN), ammonia (ionized NH_4^+ and unionized NH_3), nitrate plus nitrite (NO_3 + NO_2), and total dissolved nitrogen (TDN) were filtered within 12 hours of collection using ashed glass fibre filters. Total ammonia, total nitrate and total nitrite concentrations were determined from unfiltered samples of hatchery effluents. Total organic nitrogen (TON) in stream samples was calculated using the equation:

$$TON = (PN + TDN) - (NH_3 + NO_3 + NO_2)$$

Samples for total phosphate analysis were collected in 100 mL "Sovall" glass bottles (with teflon cap liners). Dissolved ortho-phosphate was analyzed in filtered samples, but levels seldom were above the analytical detection limit ($2\ ug \cdot L^{-1}$).

pH was measured in the field using a Sargent-Welch (Model RB) pH meter, equipped with a combination temperature/pH glass electrode. River temperatures were measured using hand-held mercury thermometers during routine sampling.

Volumetric stream flow data were obtained from IWD, B.C. Hydro, DFO, or SEP. Water velocities at sampling sites were measured using a Price-type rotational current meter (Model 622, Gurley Co., Troy, New York) or a Marsh-McBirney electronic current meter (Model 201, Gaithersburg, Maryland).

PERIPHYTON

Field Methods

Artificial substrates were used to quantify periphyton accumulations in this study to avoid problems associated with quantitative sampling of natural substrates, such as heterogeneous environment, patchy periphyton distribution, and irregular sampling surfaces, (Weitzel 1979; Whitton 1979). The artificial substrate developed by Stockner and Shortreed (1976) for use in coastal streams with variable flows was used in this study (Fig. 4). The growth surface was a 30 cm x 20 cm plexiglass plate roughened with steel wool, with a 400 cm^2 sampling area scribed onto the surface. The plexiglass plate was attached horizontally to a 45 kg concrete block and was stable under most flow conditions. The plate was raised 3 cm above the block by plastic washers on brass posts.

The artificial substrates used in many streams (listed in Table 2) were located at sites with similar stream substrates, levels of exposure to sunlight, flows, and depths. Duplicate substrates were placed in riffles (flows greater than 40 $cm \cdot sec^{-1}$) and pools (flows less than 20 $cm \cdot sec^{-1}$) in most streams. Low flow areas near shore or behind boulders frequently were used as pool habitats.

Artificial substrates were placed in streams for three weeks during spring, summer, and autumn, and for up to six weeks during winter to establish periphyton assemblages similar to those on the surrounding stream bottom (Collins and Weber 1978). Periphyton from natural substrates were sampled to compare qualitatively with periphyton on artificial substrates. Algae were examined using a microscope and estimates were made of the relative abundance of common species.

Periphyton accumulations were scraped from the upper surfaces of the plexiglass plates. Each sample was split into four subsamples and stored in plastic vials. Two were preserved with Lugol's solution for species identification and enumeration and two were transported on ice to the EPS/DFO Chemistry Laboratory for biomass analyses. When periphyton accumulations were too small to subsample, the unsplit samples were used for species identification and diatom enumeration.

The plexiglass plates were scrubbed, then returned to the stream. The depth between the water surface and the artificial substrate was measured. Water velocity was measured at the height of the plate. Substrate positions were adjusted to minimize flow differences between duplicate substrates and among sites in a stream.

The artificial substrates were stable in the streams except when flows were extremely variable. Floods which followed heavy rainfall often scoured plates and stream bottoms, so longer exposure periods were required for algal recolonization. Some sites were inaccessible during floods. Equipment was vandalized occasionally at the Capilano (site 3), Quinsam (site 4), Puntledge (site 3), and Chilliwack Rivers.

Laboratory Methods

Two unpreserved periphyton samples from each site were analyzed for biomass accumulations at the EPS/DFO laboratory. Organic weight (ash-free dry weight, after 4 hours at 500°C) and photosynthetic pigments (chlorophyll a and phaeopigment) were measured. Pigments were extracted by sonication in 90% acetone, then measured spectrophotometrically. Lorenzen's (1967) equation was used to calculate chlorophyll a and phaeopigment concentrations.

One preserved subsample was examined microscopically to identify species of green algae, blue-green algae, chrysophytes, red algae, and diatoms. Relative proportions of non-diatom species and dead diatoms were estimated in each sample.

The other preserved subsample was prepared for diatom species identification and enumeration using a boiling nitric acid procedure (Stockner and Costella 1980). Measured amounts of prepared diatom subsamples were mounted on coverslips and fixed permanently to microscope slides using Hyrax mounting medium (Custom Research and Development, Inc., Auburn, California). Diatom species were enumerated and identified at 1000 X magnification. At least 500 diatom cells were enumerated in each sample. Counts of this magnitude are expected to have ± 10% accuracy (0.95 confidence limits) when distributed randomly in the sample (Lund *et al*. 1958). Data were transformed to cells per m^2 and percent abundance for each species. Species considered common for this report comprised at least 5% relative abundance on five or more sampling occasions. Periphyton species distribution among all streams sampled is described in Appendix I.

BENTHIC INVERTEBRATES

Field Methods

Benthic invertebrates were sampled at four sites in each stream, chosen for similar substrates, water depths, water velocities (*ca*. 40-60 $cm \cdot sec^{-1}$) and light regimes. Invertebrates were sampled using a modification of Mundie's (1971) method and sampler (an improved Surber sampler with enclosed sides, current control, a sampling area of 0.18 m^2, and a collecting net mesh size of 250 um) (Fig. 5). On each sampling date, replicate samples were taken at each site, placed in 2 L wide-mouth plastic containers, and immediately preserved with 70% isopropanol.

The Quinsam, Capilano, Big Qualicum, Conuma and Eagle Rivers and Loon and Finn Creeks had cobble substrates. Six replicate samples were taken at each site, of which four were analyzed. The Puntledge River had bedrock and cobble substrates; hence, three replicate samples were taken from bedrock and three from cobble areas at sites 2, 3, and 4. Three replicate samples were taken from the cobble substrate at site 1, the control site for the Puntledge River (at the upstream end of the spawning channel). Although samples from bedrock substrates were analyzed, data were not included in this report because they were highly variable and could not be compared to other rivers.

Laboratory Methods

Rose Bengal stain was added to the samples, large insects were removed and counted, then samples were split using a "Folsom" plankton splitter (McEwan et al. 1954) until a fraction containing 100 to 200 organisms was obtained. This subsample size was considered to give a reliable estimate of total abundance, after subsamples of various sizes (100 to 400 organisms) were compared. Invertebrates were enumerated, identified, and stored in isopropanol and glycerol. Standard taxonomic texts were used to identify invertebrates to family or genus where possible. Oligochaetes were identified to species in selected samples from the Quinsam, Puntledge, and Big Qualicum Rivers by D.F. McAlpine (Museum of Natural Sciences, Ottawa) and K. Coates (Institute of Ocean Sciences, Sidney, B.C.).

Invertebrate abundance (organisms per m^2) was calculated from the number of organisms per replicate sample, and means for each site were calculated. The most frequently occurring orders of invertebrates were Ephemeroptera, Plecoptera and Trichoptera (considered together because of ecological similarities), Diptera, Oligochaeta, Hydracarina, Ostracoda and Copepoda. The abundances of these orders were used in statistical analyses. Distribution of benthic invertebrate taxa among all streams sampled is listed in Appendix II.

STATISTICAL METHODS

Significant differences among sites in physical and chemical parameters, periphyton biomass, and invertebrate abundance were assessed using analysis of variance (ANOVA, $P<0.05$ or 0.01). Dunnett's test ($P<0.05$) was used to compare control sites with downstream sites. The Student-Newman-Keuls test (SNK) was used to compare downstream sites within each river.

The ratio of dissolved inorganic nitrogen to total phosphorus (N:P) was calculated from concentrations of ammonia, nitrate and total phosphate measured during the periphyton growing seasons (Miller et al. 1978).

Annual estimates of periphyton biomass accumulation (chlorophyll a, organic weight) were calculated by integrating values measured over one year. The autotrophic index was calculated from the ratio of periphyton organic weight to chlorophyll a concentrations (Collins and Weber 1978). Diversity was calculated for diatom species and benthic invertebrate genera using the Shannon-Weaver formula (Moss 1973), as follows:

$$d = -\sum_{i=1}^{s} \frac{n_i}{N} \ln \frac{n_i}{N}$$

where: d equals diversity

n_i equals the number of individuals of the i^{th} species or genus.

N equals the total number of individuals

s equals the number of species or genera in the sample.

Similarities among diatom assemblages within each river were determined using Sullivan's similarity index, S (Tuchman and Blinn 1979), as follows:

$$S = \frac{\sum_{i=1}^{s} P_{ij} P_{in}}{\sqrt{\sum_{i=1}^{s} P_{ij}^2} \sqrt{\sum_{i=1}^{s} P_{in}^2}}$$

where: S equals similarity.

P_{ij} and P_{in} equal the proportions of the i^{th} species in the j^{th} or n^{th} assemblages.

s equals the number of species.

This index also was used to compare species composition in the Quinsam, Puntledge, Big Qualicum and Capilano Rivers using annual percent abundance data for the sites.

Similarities among invertebrate samples within each river were calculated using Whittaker and Fairbanks' (1958) formula for percent similarity (PS) at the generic level:

$$PS = 100\,[1.0 - 0.5 \sum_{i=1}^{s} |P_{ij} - P_{in}|]$$

where: PS equals percent similarity

P_{ij} and P_{in} equal the proportions of the i^{th} species in the j^{th} or n^{th} assemblages.

s equals the number of species.

Linear and multiple regression analyses were used to assess the importance of several physical and chemical parameters (temperature, flow over artificial substrates, nitrate, ammonia, total organic nitrogen, total phosphate, and silica) on periphyton chlorophyll a accumulations upstream and downstream of hatchery discharges. Data from the 1979 periphyton growing seasons were analyzed for the Quinsam, Puntledge, Big Qualicum and Capilano Rivers.

Phosphate and ammonia loading ($kg \cdot d^{-1}$) in effluents from the Quinsam, Puntledge, Big Qualicum and Capilano Rivers were calculated using effluent total phosphate and ammonia concentrations and hatchery flow volumes.

RESULTS

QUINSAM RIVER

Water Chemistry

General Characteristics: Quinsam River water was slightly basic (pH 7.1 to 7.8) and low in hardness (15 to 45 $mg \cdot L^{-1}$ $CaCO_3$) from August 1978 to October 1979. Water temperatures ranged from 0.5 to 18°C (Fig. 6). River flows were controlled from June to August and were high during winter (1979 annual flow range: 20 to 1250 $m^3 \cdot min^{-1}$) (Fig. 7). During summer, water was stored for hydro-electric generation at Wokas Lake. There were no significant differences (ANOVA) in mean concentrations of any chemical parameters, except certain nutrients, among sites upstream and downstream of the Quinsam Hatchery (Table 5).

Nutrient Concentrations: Total phosphate concentrations ranged annually from 3 to 50 $ug \cdot L^{-1}$ (Table 6, Fig. 8), with lowest levels measured at site 1 and highest levels at site 2. There were no significant differences in data averaged annually. However, during the periphyton growing season (May to September), total phosphate concentrations were higher at sites 2, 3, and 4 than at site 1 (Dunnett's, $P<0.05$; SNK). Total phosphate concentrations were higher in the Quinsam River tributary Cold Creek than at site 1, but no statistical comparisons were made.

Ammonia concentrations ranged annually from below detection (2 $ug \cdot L^{-1}$) to 65 $ug \cdot L^{-1}$ (Table 6, Fig. 9). Ammonia levels were higher at sites 2 and 3 than at sites 1 and 4 during the periphyton growing season (Dunnett's, $P<0.05$; SNK), but mean annual values did not differ significantly. Maximum ammonia levels were recorded at site 2.

Nitrate concentrations ranged from 10 to 70 $ug \cdot L^{-1}$ between late spring and autumn 1979. Maximum nitrate levels (470 $ug \cdot L^{-1}$) were measured during early winter 1978 (Fig. 10). Nitrate concentrations were higher at site 2 than at site 1 (Dunnett's, $P<0.05$) during the periphyton growing season. Nitrate concentrations were higher in the Quinsam River tributary Cold Creek than at site 1, although statistical analyses were not performed (Table 6).

Mean N:P ratios calculated for the growing season ranged from 2.8:1 to 5.0:1 (Table 6). Ratios were highest at site 1 and lowest at site 2.

Hatchery Operations: Cold Creek was the major source of rearing water for the Quinsam Hatchery. As a result, the hatchery effluent was similar to Cold Creek water in general chemical composition (Table 5). However, phosphate and ammonia concentrations were higher in the effluent than in the Quinsam River or Cold Creek (Table 6). Statistical comparisons were not made because dissolved concentrations were measured in river water and total concentrations were measured in the effluent.

Between 3400 and 30,000 kg of fish were reared in the Quinsam Hatchery during the study period (Fig. 11). The maximum biomass of fish occurred during March and early April 1979, and the minimum in late April and June 1979. The amount of food supplied to the fish was greater in winter and spring than in summer (Fig. 11). The greatest amounts were supplied during May and July 1979 (400 $kg \cdot d^{-1}$), and the lowest amounts in November 1978 (75 $kg \cdot d^{-1}$).

Periphyton

Biomass: Mean chlorophyll *a* and phaeopigment concentrations (Table 7), and diatom numbers (Table 8) on artificial substrates in the Quinsam River were significantly higher at sites 2 and 3 than at site 1 (ANOVA, $P<0.01$; Dunnett's, $P<0.05$) and higher at site 2 than at site 4 (SNK). Water velocity over the artificial substrates differed among sites (Table 7) (ANOVA, $P<0.05$,SNK), with lowest pool flows at site 1 and lowest riffle flows at site 2.

Seasonal patterns of chlorophyll *a* and organic weight accumulations are shown in Fig. 12a and 12b. The growing season occurred between May and October 1979, with peaks in June and October at all four sites and in August at site 2. Site 2 had the largest June peak and the only August peak. The major peak at sites 1, 3, and 4 occurred in October, and was largest at site 3. The maximum chlorophyll *a* concentration (75 $mg \cdot m^{-2}$) was recorded in June and August at site 2 riffles and in October at site 3 pools.

Species Composition: During winter, small amounts of the diatoms *Achnanthes minutissima*, *A. linearis* var. *pusilla*, *Synedra rumpens* and *Cymbella minuta* were present in the Quinsam River. *Nitzschia* cf. *fonticola* was common downstream of the hatchery.

During summer 1979, diatoms were the most abundant algae (Fig. 13a, 13b, 14a, 14b; Table 8). In the June and August periphyton peaks, *A. minutissima* was predominant at sites 1, 3, and 4, especially in riffles. *Nitzchia palea* and *Navicula pelliculosa* were predominant in the peak accumulations at site 2 and were common at sites 3 and 4. *Synedra rumpens*, *S. ulna*, and *Gomphonema angustatum* decreased in abundance downstream of the hatchery, whereas *Ni.* cf. *fonticola*, *Diatoma vulgare*, *Cymbella minuta*, *C. minuta* var. *silesiaca* and *C. sinuata* increased in abundance.

The green algae *Ulothrix* spp. (*U. zonata*, *U. tenuissima*) were abundant at sites 1 and 3 during summer. Other common green algae included *Oedogonium* spp., *Spirogyra* spp., and desmids (site 1), *Draparnaldia plumosa* (sites 1 and 2), and *Tetraspora* sp. (site 3). The blue-green alga *Plectonema notatum* was common at site 2.

The October 1979 peak in the Quinsam River was composed largely of *Ulothrix* spp., which were most abundant at site 3. Diatom species composition was similar in summer and autumn, except that *A. minutissima* and *Ni.* cf. *fonticola* (rather than *Ni. palea*) were the most abundant diatoms downstream of the hatchery in autumn.

The mean similarity index for diatom species composition ranged from 0.64 to 0.90, with greatest similarity among downstream sites, particularly at sites 3 and 4. Site 1 was more similar to site 4 than to sites 2 and 3. Diversity indices for the diatom assemblages ranged from 1.2 to 1.9, with few significant differences among sites. Species diversity was lowest for site 1 riffles. The mean number of diatom species per sample ranged from 22 (at site 1 riffles) to 34 (at site 1 pools) (Table 7). There were fewer species in riffles than in pools.

Benthic Invertebrates

Abundance: There were significantly fewer benthic invertebrates upstream of the Quinsam Hatchery than downstream (ANOVA, $P<0.05$; Dunnett's, $P<0.05$) (Table 9). Benthic invertebrates were more abundant at site 3 than at site 2 (SNK). Mean densities ranged from 10,000 (site 1, March 1979) to 91,000 organisms$\cdot m^{-2}$ (site 3, August 1978) (Fig. 15). At sites 1 and 2, benthic invertebrates were most abundant in September 1979; at site 4, they were least abundant in March 1979 (SNK). Site 3 had no significant differences in abundance among the three sampling periods.

Composition: Diptera (mainly Chironomidae) were predominant at sites 1, 3, and 4 in the Quinsam River during all sampling periods, whereas Oligochaeta were predominant at site 2. No differences in abundance (ANOVA) of Ephemeroptera, Plecoptera, Trichoptera and Ostracoda were measured among the four sites (Tables 9, 10). However, Diptera were most abundant at sites 3 and 4, Oligochaeta at site 2, Hydracarina at site 3, and Copepoda at site 2 (Dunnett's, $P<0.05$; SNK).

The chironomid Rheotanytarsus was the predominant genus at sites 1, 3 and 4, but was less abundant at site 2. Naidid oligochaetes (unidentified naidids, Nais sp. and N. elinguis) were predominant at site 2. The chironomids Cricotopus, Micropsectra and Polypedilum and the mayfly Ephemerella inermis were common at all sites. Statistical analyses were not performed at the generic level.

The diversity index (calculated for genera) ranged from 2.9 at site 2 to 4.3 at site 1. Sites 3 and 4 were most similar in composition (Percent Similarity, PS=59) and sites 1 and 2 were least similar (PS=34).

PUNTLEDGE RIVER

Water Chemistry

General Characteristics: Puntledge River water was slightly basic (pH 7.0 to 7.6) and low in hardness (16 to 20 $mg \cdot L^{-1}$ $CaCO_3$) from August 1978 to July 1980. Water temperatures ranged from 3.5 to 20°C (Fig. 16). River flows usually ranged from 175 to 1250 $m^3 \cdot min^{-1}$, with minimum flows during winter (Fig. 17). Flows of up to 7000 $m^3 \cdot min^{-1}$ occurred during occassional releases of flood waters from the reservoir. Concentrations of all water chemistry variables, except total phosphate and ammonia, were statistically similar (ANOVA) at the four sites throughout the year (Table 11).

Nutrient Concentrations: Total phosphate concentrations ranged from below detection (2 $ug \cdot L^{-1}$) to 9 $ug \cdot L^{-1}$ (Fig. 18). Mean total phosphate levels were lowest at site 1 (Dunnett's, $P<0.05$) and similar among sites 2, 3, and 4 (SNK) throughout the year (Table 12).

Ammonia concentrations ranged from below detection (2 $ug \cdot L^{-1}$) to 21 $ug \cdot L^{-1}$ (Fig. 19). The mean ammonia concentration was lower at site 1 than at site 2 (Dunnett's, $P<0.05$) throughout the year (Table 12), and was similar at sites 2, 3 and 4 (SNK).

Nitrate concentrations ranged from 10 to 60 $ug \cdot L^{-1}$ (Fig. 20), with minimum values during summer and maximum values during winter. There were no significant differences in nitrate concentrations among sites (Table 12).

Mean N:P ratios ranged from 14:1 to greater than 23:1 during the spring growing season and from 12:1 to greater than 17:1 for the year (Table 12). Ratios were highest at site 1 and lowest at site 2.

Hatchery Operations: The general chemical composition of Puntledge Hatchery effluent was similar to that of the river (Table 11). However, total phosphate and ammonia concentrations were higher in the effluent than in the Puntledge River (Table 12). Statistical comparisons were not made because dissolved concentrations were measured in river water and total concentrations were measured in the effluent.

During the study period, up to 12,000 kg of fish were reared in the Puntledge Hatchery (Fig. 21). Maximum fish biomass occurred during April (6800 kg in 1979; 12,000 kg in 1980) and minimum biomass in late May and June (1400 kg in 1979; 1900 kg in 1980). Food was provided to the fish at rates of 24 to 166 $kg \cdot d^{-1}$ (Fig. 21), with lowest amounts provided during late autumn and winter and greatest amounts during spring.

Periphyton

Biomass: Mean periphyton chlorophyll a, phaeopigment, and organic weight concentrations (Table 13) and diatom numbers (Tables 14a, 14b) on artificial substrates in the Puntledge River were highest at site 2 (ANOVA, $P<0.01$; Dunnett's, $P<0.05$; SNK). Water velocity over the artificial substrates differed among sites (ANOVA, $P<0.01$) (Table 13), with fastest pool flows at site 3 and slowest riffle flows at site 1.

Seasonal patterns of chlorophyll a and organic weight accumulations are shown in Fig. 22a and 22b. Peak accumulations occurred from March to May downstream of the Puntledge Hatchery. Small peaks occurred in October 1978 and 1979 at all sites. Maximum chlorophyll a concentrations were measured in pools during spring at site 2 (511 $mg \cdot m^{-2}$ in 1979; 204 $mg \cdot m^{-2}$ in 1980). Biomass was very low at site 1, increased sharply at site 2, and decreased sharply at sites 3 and 4.

Floods scoured natural and artificial substrates at all sites in the Puntledge River in April 1979 and in March 1980, except in protected pool areas at site 2. Because access to the sites was limited during floods, substrates were left in the river for 35 days during the 1979 peak, and 25 days during the 1980 peak.

Species Composition: Site 1 was located in the Puntledge Hatchery spawning channel, where the diatoms *Tabellaria* fenestrata, Achnanthes minutissima and Synedra rumpens were predominant (Table 14a, 14b). Periphyton accumulations were so small that results from site 1 were not included in Figs. 23 and 24, describing species composition.

Downstream of the Puntledge Hatchery, the green algae Ulothrix spp. (U. zonata, U. tenuissima, U. tenerrima) were predominant during the spring peaks, with 50 to 80% of total accumulation (Fig. 23a, 23b). Greatest Ulothrix accumulations were measured at site 2 pools.

Diatoms were very abundant during spring (Fig. 24a, 24b; Table 14a, 14b). In pools, A. minutissima, Hannaea arcus and Synedra spp. were abundant at sites 2, 3, and 4. Nitzschia palea, Ni. cf. fonticola, Fragilaria crotonensis, and F. capucina var. mesolepta were the predominant diatoms at site 2 in the May 1979 peak. In riffles at sites 2, 3, and 4, A. minutissima and H. arcus were the predominant diatoms, and Gomphonema angustatum and Synedra spp. were common. Nitzschia spp. were common at site 2 riffles.

Small amounts of diatoms and green algae were present during summer. A. minutissima was predominant and S. rumpens, S. ulna, Gomphonema spp. and the green algae Ulothrix spp., Spirogyra spp., Stigeoclonium stagnatile and Oedogonium spp. were common. Green algae were more abundant at site 2 than sites 3 and 4.

In the small October 1979 peak at site 2, the predominant algae were Oedogonium spp. in pools and S. stagnatile in riffles. Species composition at sites 3 and 4 was similar in summer and autumn.

Winter periphyton accumulations were the lowest for the year, but were greater than in other coastal rivers. A. minutissima was predominant at all sites; Nitzschia spp. and Cymbella spp. were common at site 2, and Synedra spp. and Gomphonema spp. were common at sites 3 and 4. Ulothrix spp. became increasingly abundant throughout winter in the pools. The chrysophyte Hydrurus foetidus was common in site 2 riffles during late winter. Riffle substrates had many blackfly (Simuliidae) larvae and pupae on them during winter.

The mean similarity index for diatom species composition ranged from 0.31 to 0.92, with lowest values for comparison of site 1 and the downstream sites. The three downstream sites were very similar in composition. Diversity indices for the diatom assemblages ranged from 1.3 to 2.0, and were higher in pools than in riffles. The diversity index was greatest at site 2. The mean number of diatom species counted per sample ranged from 24 to 38, and was greatest at site 1 (Table 13). There were more diatom species in pools than in riffles.

Benthic Invertebrates

Abundance: Benthic invertebrates in the Puntledge River were more abundant at sites 2 and 3 than at sites 1 and 4 (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK) (Table 15). Mean densities ranged from 6,000 (site 1, June 1979) to 95,000 organisms$\cdot$m^{-2} (site 2, March 1979) (Fig. 25). At site 1, invertebrates were more abundant in March 1979 than in June 1979; at site 3, they were more abundant in March 1979 than in August 1978 (SNK). At sites 2 and 4, there were no significant differences in abundance among the three sampling periods.

Composition: Diptera (principally Chironomidae) were predominant at sites 1, 2, and 3 (Table 16). Plecoptera, Trichoptera and Ephemeroptera (considered as one group) were predominant at site 4, and very common at sites 1, 2 and 3. Densities of all orders, except Ostracoda, differed significantly among sites (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK). The Plecoptera, Trichoptera, and Ephemeroptera group was more abundant at sites 2 and 3 than at site 1. Diptera and Copepoda were most abundant at site 2. Oligochaeta were more abundant at site 2 than at site 1. Hydracarina were more abundant at site 3 than at site 1.

The most common genera were the chironomids *Rheotanytarsus* (at sites 2 and 3) and *Cricotopus* (at site 2), with the greatest numbers occurring during spring. Other common taxa included naidid, lumbriculid and enchytraeid oligochaetes (at site 2), the copepod *Cyclops bicuspidatus thomasii* (at sites 1 and 2), the mayfly *Pseudocloeon* sp. (at sites 3 and 4), and the caddisflies *Cheumatopsyche* sp. and *Hydropsyche* sp. (at site 2). Statistical comparisons were not performed at the generic level.

The diversity index, calculated for genera, ranged from 3.8 at sites 2 and 4 to 4.2 at site 1. Sites 1 and 3 were least similar in composition (PS=33), and sites 3 and 4 were most similar (PS=56).

BIG QUALICUM RIVER

Water Chemistry

General Characteristics: Big Qualicum River water was slightly basic (pH 7.4 to 8.0) and moderately low in hardness (31 to 44 mg$\cdot$L^{-1} $CaCO_3$) from August 1978 to September 1979, and from May to September 1980. Water temperatures ranged from 3.5 to 15°C, and were greatest during May and June (Fig. 26). Big

Qualicum River flows ranged from 75 to 500 $m^3 \cdot min^{-1}$ during the study period, with lowest flows during summer (Fig. 27). No significant differences (ANOVA) in chemical composition, except for nutrients, were measured among the six sites (Table 17).

Nutrient Concentrations: Total phosphate concentrations ranged from 4 to 34 $ug \cdot L^{-1}$ between September 1978 and mid-August 1979 (Fig. 28), but increased greatly (up to 160 $ug \cdot L^{-1}$) at sites 4, 5, and 6 during late August and September 1979. During that period, gravel was replaced in the chum spawning channel upstream of site 4. There were no significant differences (ANOVA) in mean annual total phosphate concentrations among the six sites (Table 18). However, during the periphyton growing seasons (June to September), total phosphate concentrations were higher at sites 4, 5, and 6 than at sites 1, 2, and 3 (Dunnett's, $P<0.05$; SNK).

Ammonia concentrations in the Big Qualicum River ranged from below detection (2 $ug \cdot L^{-1}$) to 130 $ug \cdot L^{-1}$ (Fig. 29). Ammonia concentrations were greatest in December 1978 and smallest in October 1978. Ammonia concentrations were higher at sites 4, 5, and 6 than at sites 1, 2, and 3 (Dunnett's, $P<0.05$; SNK) during the periphyton growing seasons and throughout the year (Table 18). During the growing season, ammonia concentrations were greatest in late May 1979 at sites 4, 5 and 6.

Nitrate concentrations ranged from 10 $ug \cdot L^{-1}$ (summer and autumn 1979, 1980) to 125 $ug \cdot L^{-1}$ (spring 1979) (Fig. 30). The mean annual nitrate concentration (Table 18) was lower at site 1 than at sites 4, 5 and 6 (Dunnett's, $P<0.05$; SNK). Nitrate concentrations were higher during summer 1980 than summer 1979.

The mean N:P ratios calculated for the growing season ranged from 3.4:1 to 4.5:1 in 1979 and from 5.1:1 to 8.4:1 during 1980 (Table 18). Ratios were highest at sites 1 and 2.

Total dissolved nitrogen (TDN), total organic nitrogen (TON), and particulate nitrogen (PN) concentrations in the Big Qualicum River were higher at sites 4, 5, and 6 than at sites 1, 2, and 3 during the 1979 and 1980 growing seasons (Dunnett's, $P<0.05$; SNK).

Hatchery Operations: Effluents from the Big Qualicum experimental channel and the main hatchery were similar in general chemical composition to river water (Table 17). However, ammonia and total phosphate concentrations in effluents from the main hatchery were greater than from the experimental channel and the river. Ammonia concentrations were greater in the effluent of the experimental channel than at sites 1, 2 and 3 (Table 18).

Statistical comparisons were not made because dissolved concentrations were measured in river water and total concentrations were measured in the effluent.

The greatest fish biomass in the Big Qualicum Hatchery during the study period occurred in May (22,000 kg in 1979; 30,000 kg in 1980) and the lowest biomass in June (1600 kg in 1979 and 1980) (Fig. 31). The daily feeding rate was lowest in December and June (39-68 $kg \cdot d^{-1}$) and highest in May (767 $kg \cdot d^{-1}$) (Fig. 31).

Periphyton

During summer, artificial substrates downstream of the Big Qualicum Hatchery were covered by drifted mats (up to 0.5 m long) of the filamentous green alga *Cladophora glomerata*. *Cladophora* grew in hatchery rearing channels, however mats periodically were sloughed into the river. The distribution of *Cladophora* and other periphyton on natural substrates at the six river sites and in the hatchery channels was documented during summer 1980 using stream transects.

Biomass: Mean chlorophyll *a*, phaeopigment, organic weight concentrations (Table 19) and diatom numbers (Table 20) on artificial substrates did not differ significantly (ANOVA) at sites 1, 2, and 3. However, accumulations appeared to be lower at site 1 than at sites 2 and 3, downstream of the experimental rearing channel. No statistical comparisons were made with data from sites 4, 5 and 6 because biomass accumulations were underestimated due to drifted *Cladophora*. Flow over artificial substrates was similar at sites 1, 2 and 3 (ANOVA, $P<0.05$) (Table 19).

Seasonal patterns of chlorophyll *a* and organic weight accumulations are shown in Fig. 32 for riffle substrates only, because there were no suitable pool areas. A small biomass peak was measured at site 4 in January 1979. The growing season was from June to September 1979, with maximum accumulations between mid-June and late July. The maximum chlorophyll *a* concentration at site 1 was 46 $mg \cdot m^{-2}$; at sites 2 to 6 it ranged from 222 to 264 $mg \cdot m^{-2}$. No quantitative data were collected at sites 4, 5 and 6 after June 1979 because of the presence of drifted *Cladophora* on artificial substrates.

Species Composition: From autumn 1978 to spring 1979, small amounts of blue-green algae (*Plectonema notatum*, and *Lyngbya digueti*) and diatoms were present in the Big Qualicum River. Upstream of the main hatchery, *P. notatum*, *L. digueti*, and *Achnanthes minutissima* were predominant; and downstream, *P.*

notatum, A. minutissima, and Cymbella minuta were predominant. C. minuta was very abundant in the January biomass peak at site 4, along with C. minuta var. silesiaca and A. minutissima. The C. minuta peak was associated with decaying fish carcasses in the river and heavy accumulations of the bacterium Sphaerotilus natans (sewage fungus) in the river and on artificial substrates.

Between June and September 1979, Ulothrix spp. (U. zonata, U. tenuissima) and diatoms were the most abundant algae (Fig. 33). Ulothrix spp. predominated in the biomass peaks, with progressively increasing abundance and predominance downstream of site 1. Navicula pelliculosa was the predominant diatom at all sites (Fig. 34, Table 20). Diatoma vulgare was abundant at sites 2 and 3, and common at sites 4, 5, and 6. Other common species included A. minutissima, Nitzschia palea, Ni. cf. fonticola, Hannaea arcus and Cymbella spp. H. arcus was more abundant upstream and Nitzschia spp. and Cymbella spp. were more abundant downstream of the main hatchery. However, Cladophora coverage reduced the reliability of information collected at sites 4, 5, and 6.

The mean similarity index for diatom species composition ranged from 0.57 to 0.89. Diatom assemblages at the upstream sites (sites 1, 2 and 3) were similar in composition, as were assemblages at downstream sites (sites 4, 5 and 6). Site 3 occupied a middle position, with similarities to upstream and downstream sites. Diversity of the diatom assemblages increased progressively downstream from 1.4 (site 1) to 1.7 (site 4, 5, 6). Mean numbers of diatom species per sample ranged from 24 to 28 (Table 19).

Periphyton Accumulations on Natural Substrates: Periphyton accumulations on natural substrates in the Big Qualicum River were sampled during summer 1980. Cladophora glomerata was abundant in rearing channels and the concrete raceway of the Big Qualicum Hatchery. In the river, it was rare at sites 1 and 3 and common at sites 4 and 6. Drifted Cladophora was less abundant downstream of the hatchery in 1980 than in 1979.

Periphyton accumulations were heaviest in July 1980 at all sites. In midstream riffle areas upstream of the main hatchery, the blue-green alga Chamaesiphon sp. and a thin film of Lyngbya digueti and diatoms were more abundant at sites 2 and 3 than at site 1. Downstream of the main hatchery, 2 to 5 mm thick accumulations of Ulothrix spp., L. digueti and diatoms were found, and were heaviest at site 6. Among diatoms, Hannaea arcus, Synedra rumpens, Gomphonema angustatum and G. parvulum were common at site 1. Diatoma vulgare, S. ulna, Cocconeis placentula and Cymbella spp. were increasingly abundant downstream of site 1. Species such as Achnanthes minutissima, *Navicula pelliculosa* and *Nitzschia* spp. could not be identified without more detailed diatom analyses.

Slow flowing areas near shore at site 1 contained mosses, *Ranunculus aquatilis* (a vascular plant), *Phormidium autumnale*, *Chamaesiphon* sp., and a thin diatom film. Downstream of site 1, progressively thicker layers of *Ulothrix* spp., *L. digueti* and diatoms accumulated. Thick algal mats were evident at sites 4, 5, and 6.

Benthic Invertebrates

Abundance: Benthic invertebrate abundance differed significantly among the eight sites in the Big Qualicum River during the five sampling periods (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK) (Table 21). Mean invertebrate abundance ranged from 14,000 (site 1, March 1979), to 226,000 organisms$\cdot$m^{-2} (site 6, August 1978) (Fig. 35). During August 1978, sites 1, 2, 4, and 6 were sampled; there were higher numbers at site 6 than at site 1. Sites 1, 2, 4, and 6 were sampled during March 1979; there were higher numbers at site 4 than at site 1. Sites 3, 3a, 4, and 6 had similar numbers in June 1979. Samples taken at sites 1, 2, 2a and 3 in July 1979 exhibited more organisms at site 1 than at site 2. Sites 3a, 4, 5, and 6 were sampled during September 1979; there were higher numbers at site 4 than at sites 3a and 5.

Composition: Diptera (principally Chironomidae) were the predominant invertebrates at all sites in the Big Qualicum River (Table 21). The Plecoptera, Trichoptera, and Ephemeroptera group was common at sites 1, 2, 2a, 3, and 3a, and had similar numbers upstream and downstream of the hatchery. Oligochaeta and Copepoda were common downstream of the hatchery.

There were significant differences among sites and sampling periods in abundance of certain orders of benthic invertebrates (Dunnett's, $P<0.05$; SNK) (Table 21). In September 1978, Ostracoda were most abundant at site 2; Copepoda were more abundant at site 6 than site 1; and Diptera, Oligochaeta, and Hydracarina were most abundant at site 6. In March 1979, Diptera were most abundant at site 4 and Ostracoda were most abundant at site 2. In June 1979, Ephemeroptera, Plecoptera and Trichoptera were more abundant at site 3a than at site 6. In July 1979, more Ostracoda and fewer Diptera were found at site 2 than sites at 1, 2a and 3; Plecoptera, Trichoptera, and Ephemeroptera were most abundant at site 1. In September 1979, Diptera were most abundant at sites 4 and 6; Oligochaeta were most abundant at sites 4 and 5; Copepoda were least abundant at site 5; and Hydracarina were more abundant at site 3a than at site 5.

The chironomids *Cricotopus*, *Eukiefferiella*, and *Micropsectra* were the most common genera in the Big Qualicum River. *Cricotopus* and *Eukiefferiella* were most abundant downstream of the hatchery, but *Micropsectra* was equally abundant upstream and downstream. Naidid oligochaetes (*Nais* sp., *N. communis*, and unidentified naidids) were abundant downstream of the hatchery. Low numbers of enchytraeid and lumbriculid oligochaetes occurred upstream and downstream of the hatchery. *Limnodrilus hoffmeisteri* and other tubificid oligochaetes were visually abundant in hatchery rearing channels. Other common organisms in the river included the chironomids *Stempellinella* and *Corynoneura* upstream of the hatchery; *Rheotanytarsus*, *Rheocricotopus* and *Thienemanniella* downstream of it; and *Polypedilum* at all sites. The mayflies *Ephemerella inermis* and unidentified Heptageniidae were common upstream of the hatchery. Statistical comparisons were not performed at the generic level.

The diversity index ranged from 3.4 (at site 1) to 4.3 (at sites 3a, 4, and 6, with no trends among the eight sites. Sites 1 and 2 were similar in composition, as were sites 4 and 6 (PS = 60 to 70). Sites 1 and 4 or sites 2 and 4 were least similar (PS = 30 to 45).

CAPILANO RIVER

Water Chemistry

General Characteristics: Capilano River water was slightly acidic (pH 6.3 to 7.2) and very low in hardness (3.9 to 13.7 $mg \cdot L^{-1}$ $CaCO_3$) from September 1978 to October 1979. Water temperatures ranged from 2 to 15°C (Fig. 36). River flows were controlled at Cleveland Dam, and ranged from 75 to 7,000 $m^3 \cdot min^{-1}$ (Fig. 37). Unpredictable floods occurred throughout the year. No significant differences (ANOVA) in chemical composition, except for ammonia, were measured among the four sites (Table 22).

Nutrient Concentrations: Total phosphate concentrations ranged from below detection (2 $ug \cdot L^{-1}$) to 24 $ug \cdot L^{-1}$ (Fig. 38). Although concentrations at site 1 appeared to be lower than those downstream, they were statistically similar (ANOVA) at the four sites throughout the year (Table 23). Total phosphate concentrations were higher in the tributary, Holgate Creek, than in the Capilano River, but no statistical comparisons were made.

Ammonia concentrations ranged from below detection (2 $ug \cdot L^{-1}$) to 54 $ug \cdot L^{-1}$ (Fig. 39). Mean annual ammonia concentrations were similar at all sites (ANOVA), but growing season (May to October 1979) concentrations were higher at site 3 than at site 1 (Dunnett's, $P<0.05$) (Table 23).

Nitrate concentrations ranged from 82 $ug \cdot L^{-1}$ in summer to 400 $ug \cdot L^{-1}$ in winter (Fig. 40). There were no significant differences (ANOVA) among sites. Nitrate concentrations were higher in the tributary, Holgate Creek, than in the Capilano River (Table 23), but no statistical comparisons were made.

N:P ratios ranged from 23:1, at site 2, to greater than 45:1, at site 1 during the growing season (Table 23).

Hatchery Operations: The chemical composition of hatchery effluent was similar to Capilano River water with respect to most parameters (Table 22). However, ammonia and total phosphate concentrations were higher in effluent than in river water (Table 23). Statistical comparisons were not made because dissolved concentrations were measured in river water and total concentratations were measured in the effluent.

The biomass of fish reared at the Capilano Hatchery ranged from 85 kg in April 1979 to 13,000 kg in March 1979 (Fig. 41). Feeding rates ranged from 30 to 165 $kg \cdot d^{-1}$, with highest rates in spring and autumn and lowest rates in winter and late spring (Fig. 41).

Periphyton

Biomass: Mean chlorophyll a, phaeopigment, organic weight concentrations (Table 24) and diatom numbers (Table 25) on artificial substrates in the Capilano River were significantly higher at sites 2 and 4 than at site 1 (ANOVA, $P<0.01$; Dunnett's, $P<0.05$), and higher at site 2 than at site 4 (SNK). Data from site 3 were not analyzed because artificial substrates frequently were vandalized. Pool flows were lower at site 1 than at site 4; riffle flows were fastest at site 4 (ANOVA, $P<0.05$; SNK) (Table 24).

Seasonal variations in chlorophyll a and organic weight accumulations are shown in Fig. 42a and 42b. The growing season was from May to October 1979. The maximum chlorophyll a concentration (65 $mg \cdot m^{-2}$) was measured in August at site 2 pools. A mid-day flood on the August sampling date greatly reduced accumulations at sites 3 and 4. Biomass peaked in September at site 4.

Species Composition: During winter on the Capilano River, the diatom *Achnanthes minutissima* predominated and *Cymbella minuta* was common at all sites. Common diatoms were *Tabellaria flocculosa* and *Synedra rumpens* at site 1, *Gomphonema angustatum* and *Nitzschia* spp. at sites 2 and 3, and *Fragilaria vaucheriae* and *Diatoma hiemale* var. *mesodon* at site 4. Also common were the blue-green alga *Plectonema notatum* at sites 2 and 3 and the green algae *Ulothrix zonata* and *U. tenuissima* at site 4.

In August 1979, the green algae *Mougeotia* spp. were present at site 1 and *Ulothrix* spp. were abundant at sites 2, 3, and 4 (Fig. 43a, 43b). Throughout the summer, common green algae were *Bulbochaete* cf. *furberae* and *Geminella minor* at site 1, *Draparnaldia plumosa* and *Stigeoclonium stagnatile* at sites 2 and 3, and *Mougeotia* spp. at site 4. *A. minutissima* and *S. rumpens* were the most common diatoms, and were more abundant downstream of the hatchery than upstream (Fig. 44a, 44b; Table 25). *T. flocculosa* was common at site 1; *G. angustatum* and *C. minuta* were common at sites 2, 3, and 4. The chrysophyte *Hydrurus foetidus* was common downstream of the hatchery in June.

The mean similarity index for diatom species ranged from 0.56 to 0.89. Diatom assemblages in pools were most similar at sites 2 and 3 and least similar at sites 1 and 2 and at sites 1 and 3. Data from site 3 riffles were not analyzed; in riffles, sites 1 and 4 were not similar. Diatom species diversity ranged from 1.4 to 1.7, and was greatest at site 2. The mean number of diatom species counted per sample was greatest at site 1 (35) and least at site 4 (22) (Table 24).

Benthic Invertebrates

Abundance: Benthic invertebrates in the Capilano River were sampled during September 1979. The mean number of organisms·m^{-2} was lowest at site 1 (4,000) and highest at site 4 (115,000) (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK) (Fig. 45).

Composition: Diptera (mainly Chironomidae) were the most abundant invertebrates (Table 26) and were most abundant at site 4 (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK). Hydracarina also were most abundant at site 4. Plecoptera, Trichoptera, Ephemeroptera, Oligochaeta, Copepoda and Ostracoda had similar abundance at all sites.

The most common genera were the chironomids *Eukiefferiella*, *Cricotopus* and *Rheotanytarsus*, which were most abundant downstream of the hatchery. *Cricotopus* and *Rheotanytarsus* were most abundant at site 4. Other common organisms included the mayflies *Ephemerella inermis* (at sites 2 and 3) and *Cinygmula* sp. (at site 3), the caddisfly *Polycentropus* sp. (at site 1), and the chironomid *Micropsectra* (at site 3). Statistical analyses of benthic invertebrate data were not performed at the generic level.

The diversity index for genera ranged from 2.5 at site 4 to 3.8 at site 3. Sites 1 and 4 were most similar in composition (PS=60) and sites 1 and 3 were least similar (PS=33).

CONUMA RIVER (TLUPANA HATCHERY)

Water Chemistry

Conuma River water was slightly acidic (pH 6.6 to 7.2), with very low hardness (7 to 12 $mg \cdot L^{-1}$ $CaCO_3$). Temperatures were 3 to 6°C from March to May 1979. Chemical characteristics of the water are described in Table 27.

Nutrient concentrations did not differ significantly among the four sites (ANOVA) (Table 28). Total phosphate and ammonia concentrations ranged from below detection (2 $ug \cdot L^{-1}$) to 4 $ug \cdot L^{-1}$ Nitrate concentrations ranged from 16 $ug \cdot L^{-1}$ in May to 36 $ug \cdot L^{-1}$ in March. N:P ratios were greater than 11:1 at all sites.

Effluent total phosphate and ammonia concentrations were below detection (5 $ug \cdot L^{-1}$). Nitrate concentrations in the effluent were higher than in the Conuma River (Table 28). During March and April 1979, the hatchery reared between 353 and 882 kg of fish. Feeding rates ranged from 2 to 44 $kg \cdot d^{-1}$.

Periphyton

No significant differences in chlorophyll *a*, phaeopigment, and organic weight concentrations and diatom numbers on artificial substrates were found among sites in the Conuma River (ANOVA). Maximum chlorophyll *a* accumulations were measured in April 1979 (0.6 $mg \cdot m^{-2}$ at site 2).

On artificial substrates, the chrysophyte *Hydrurus foetidus* was predominant at sites 1 and 4 and common at sites 2 and 3, with greatest abundance at site 2. The green alga *Ulothrix cylindricum* was predominant at sites 2 and 3. *Achnanthes minutissima* was the predominant diatom at all sites. Common diatoms were *Hannaea arcus* at all sites, *Synedra rumpens* and *Gomphonema angustatum* at sites 1 and 4, and *Diatoma hiemale* var. *mesodon* at sites 2, 3 and 4.

Hatchery rearing and effluent channels and the tributary Leagh Creek contained large accumulations of Ulothrix spp. (U. zonata, U. tenuissima and U. cylindricum). Natural substrates in the Conuma River had moderate amounts of Ulothrix spp. and Draparnaldia plumosa at site 2, and small amounts further downstream. Hydrurus foetidus was present on natural substrates at all four sites in the Conuma River.

Benthic Invertebrates

Benthic invertebrates were more abundant at sites 2 and 3 (6,000 organisms$\cdot$m^{-2}) than at sites 1 and 4 (2,000 organisms$\cdot$m^{-2}) in the Conuma River (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK) (Table 29). The predominant orders were Plecoptera, Trichoptera, and Ephemeroptera (grouped together) at sites 1 and 4, Hydracarina at site 2, and Diptera (Chironomidae) at site 3. Among the four sites, there were no significant differences in numbers of Ephemeroptera, Plecoptera, Trichoptera and Copepoda (Table 29). However, Diptera and Oligochaeta were most abundant at sites 2 and 3, and Hydracarina and Ostracoda were most abundant at site 2 (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK).

The most common genera were the mayfly Cinygmula sp. (at all sites), unidentified Chloroperlidae (stoneflies, at site 4), and the chironomids Micropsectra (at site 3), Corynoneura (at site 3), and Cricotopus (at site 2).

The diversity index for genera ranged from 3.4 (at sites 3 and 4) to 3.8 (at site 1). Sites 1 and 4 were most similar in composition (PS=56), and sites 1 and 3 were least similar (PS=37).

INCHES CREEK

Water Chemistry

The waters of Inches Creek and its tributary, Barnes Creek, were slightly acidic (pH 6.2 to 6.8), with low hardness (10 to 18 mg$\cdot$L^{-1} $CaCO_3$). Temperatures were 9 to 10°C from March to May 1979. Concentrations of most chemical constituents were similar among the five sites (Table 27); however, statistical comparisons were not made.

Nutrient concentrations are listed in Table 28. Total phosphate concentrations were 7 to 14 ug$\cdot$L^{-1} at control sites in Barnes and Inches Creeks, and 18 to 41 ug$\cdot$L^{-1} downstream of the rearing area. Ammonia concentrations ranged from 7 to 36 ug·L^{-1} at the two control sites and from 19 to 61 ug·L^{-1} at the three downstream sites. Nitrate concentrations in Barnes Creek ranged from 555 to 860 ug·L^{-1}; in Inches Creek, control site values ranged from 290 to 410 ug·L^{-1}, and downstream values ranged from 350 to 580 ug·L^{-1}. N:P ratios were 63:1 in Barnes Creek and ranged from 15:1 (at site 2) to 36:1 (at site 1) in Inches Creek.

The rearing area was an impoundment created in Inches Creek; hence no effluent was sampled. The biomass of fish reared ranged from 50 kg in March to 240 kg in May. Food was provided at the rate of 12 to 98 kg·d^{-1}.

Periphyton

No reliable quantitative data were obtained from Inches Creek because artificial substrates were covered by drifted algae: the green alga *Tetraspora lubrica* at site 2 and the xanthophyte *Tribonema utriculosum* at sites 3, 4, and 5. *Tribonema* was most abundant immediately downstream of the rearing enclosure (up to 50% coverage of natural substrates). Small amounts of *Tribonema* and *Tetraspora* grew at the control site in Barnes Creek. Common diatoms in Inches and Barnes Creeks included *Eunotia arcus* var. *bidens*, *Diatoma hiemale* var. *mesodon*, *Fragilaria crotonensis*, *Meridion circulare*, *Achnanthes minutissima* and *Nitzschia palea*. The green algae *Microspora amoena* and *Draparnaldia plumosa* were common.

Periphyton were flushed out of Inches Creek during high water on the Fraser River in May and June 1979. Fraser River water backed up into Inches Creek and periphyton were stranded or swept out when flood waters receded.

LOON CREEK

Water Chemistry

The waters of Loon Creek and its groundwater-fed tributary were basic (pH 8.1 to 8.6) and relatively hard (160 to 217 mg·L^{-1} $CaCO_3$) in March, April, September and November 1980. Temperatures in the groundwater tributary were 8 to 9°C, and in Loon Creek were 4 to 12°C. Concentrations of most chemical constituents were lower in Loon Creek than in the tributary

(Table 27), but statistical comparisons were not made. Hatchery effluent is discharged into the tributary upstream of its confluence with Loon Creek.

Mean nutrient concentrations are listed in Table 28. In the tributary, total phosphate concentrations ranged from 69 to 75 $ug\cdot L^{-1}$ upstream of the effluent discharge, and from 76 to 169 $ug\cdot L^{-1}$ downstream of it. Total phosphate concentrations in Loon Creek ranged from 80 to 114 $ug\cdot L^{-1}$ at the control site, and from 78 to 164 $ug\cdot L^{-1}$ downstream of the confluence with the tributary. Ammonia concentrations in the tributary ranged from the detection limit (2 $ug\cdot L^{-1}$) to 8 $ug\cdot L^{-1}$ upstream of the effluent discharge, and from 2 to 171 $ug\cdot L^{-1}$ downstream of it. In Loon Creek, ammonia concentrations were 3 to 10 $ug\cdot L^{-1}$ at the control site and 2 to 53 $ug\cdot L^{-1}$ downstream of the tributary. Nitrate concentrations in the tributary were similar upstream and downstream of the effluent discharge (230 to 273 $ug\cdot L^{-1}$). In Loon Creek, nitrate concentrations were similar at the four sites (49 to 265 $ug\cdot L^{-1}$). The N:P ratio ranged from 1.6:1 to 1.9:1 in Loon Creek and was 3.7:1 in the tributary upstream of the effluent discharge. In Loon Creek and in the tributary downstream of the effluent discharge, nutrient concentrations were lowest in August 1980.

The Bonaparte River was sampled in August and November 1980. Total phosphate concentrations ranged from 11 to 19 $ug\cdot L^{-1}$, ammonia concentrations from less than 5 $ug\cdot L^{-1}$ to 7 $ug\cdot L^{-1}$, and nitrate concentrations from 2 to 68 $ug\cdot L^{-1}$. There were no apparent differences in concentrations in the Bonaparte River upstream and downstream of its confluence with Loon Creek.

During March and April 1980, between 790 and 1800 kg of fish were reared in the Loon Creek Hatchery. Fish were fed at rates of 9 to 38 $kg\cdot d^{-1}$. No rearing information is available for September or November 1980.

Periphyton

Natural Substrates: In March and April 1980, a thin diatom film was present in Loon Creek. In addition, mosses, diatoms and the green algae *Rhizoclonium* cf. *hieroglyphicum* and *Ulothrix* spp. grew for 25 m downstream of the tributary. *Achnanthes minutissima*, *Navicula pelliculosa*, and *Nitzschia palea* were the predominant diatoms at all sites; *Ni.* cf. *fonticola* was very common immediately downstream of the tributary. In August and November, these species occurred in greater abundance, along with *Tetraspora* sp. and *Ni. kuetzingiana* at site 2 and the macrophyte *Ranunculus* sp. at sites 1 and 4.

The tributary receiving the hatchery effluent had greater periphyton accumulations than did Loon Creek. The diatoms *A. minutissima*, *A. lanceolata*, and *Ni. palea* were abundant upstream and downstream of the discharge; but *Na. pelliculosa*, *Ni. palea* and *Ni.* cf. *fonticola*, mosses and *Rhizoclonium* were most abundant downstream.

The Bonaparte River upstream of its confluence with Loon Creek had no obvious periphyton accumulations on the sand substrate in August and November 1980. Downstream of the confluence, small amounts of *Cladophora* sp. and diatoms (*Ni. palea*, *Ni. kuetzingiana*, *Diatoma vulgare*, *Navicula radiosa* var. *tenella*, *Na. tripunctata*, and *Na. viridula*) were present on the cobble substrates. Diatoms were most abundant immediately downstream of Loon Creek in November.

Artificial Substrates: Periphyton accumulations in riffles during March and April 1980 increased in Loon Creek downstream of the tributary, with a maximum (28 mg·m^{-2} chlorophyll *a*) at site 3. The chrysophyte *Hydrurus foetidus* was predominant at sites 1 and 2. Similar diatom species occurred on artificial and natural substrates, with *Na. pelliculosa* predominant at all sites. Common species were *Fragilaria vaucheriae* at site 1, and *A. minutissima*, *Ni. palea*, and *Ni.* cf. *fonticola* at sites 2, 3 and 4.

Benthic Invertebrates

Benthic invertebrates were more abundant at sites 2 and 3 (41,000 to 45,000 organisms·m^{-2}) than at sites 1 and 4 (17,000 to 20,000 organisms·m^{-2}) in April 1980 (ANOVA, $P<0.05$; Dunnett's, $P<0.05$; SNK) (Table 30). The predominant orders were Plecoptera, Trichoptera, and Ephemeroptera (considered together) at sites 1 and 4, and Diptera (mainly Chironomidae) at sites 2 and 3 (Table 30). Plecoptera, Trichoptera, and Ephemeroptera numbers at site 1 were similar to those at downstream sites (Dunnett's, $P<0.05$) but numbers were lower at site 4 than at sites 2 and 3 (SNK). Diptera were most abundant at sites 2 and 3; Oligochaeta were most abundant at sites 2, 3 and 4; and Hydracarina were most abundant at site 2 (Dunnett's, $P<0.05$; SNK).

The most common genera were the chironomids *Cricotopus* (at sites 2 and 3) and *Heterotrissocladius* (at site 3) and the caddisfly *Anagapetus* (at all sites). Unidentified harpacticoid copepods and coleopteran larvae were common at all sites.

The diversity index ranged from 3.9 (site 4) to 4.4 (site 3). The sites were relatively similar in composition (PS=59 to 67).

HIXON CREEK (INDIAN RIVER PILOT HATCHERY)

Water Chemistry

Hatchery influent, effluent and Hixon Creek waters were somewhat acidic (pH 6.0 to 6.1), with very low hardness (2.9 to 4.4 $mg \cdot L^{-1}$ $CaCO_3$) on 29 May 1980. The Hixon Creek water temperature was 8°C. Chemical composition is described in Table 27. Concentrations of total phosphate ranged from 2 to 30 $ug \cdot L^{-1}$ and ammonia from 6 to 66 $ug \cdot L^{-1}$. Highest levels occurred in the effluent and lowest levels in Hixon Creek (Table 28). Nitrate concentrations ranged from 59 to 98 $ug \cdot L^{-1}$. The N:P ratios ranged from 7:1 (in hatchery influent water) to 30:1 (upstream of the effluent discharge).

Periphyton

Periphyton accumulations were very low on natural substrates in Hixon Creek upstream of the effluent discharge. The chrysophyte *Hydrurus foetidus* was abundant for approximately 100 m downstream of the discharge. Diatom accumulations were small, with *Achnanthes gibberula* predominant and *A. minutissima* and *Diatoma hiemale* var. *mesodon* common.

BIRKENHEAD RIVER

Periphyton

Small accumulations of the green algae *Ulothrix* spp. and the diatoms *Hannaea arcus*, *Diatoma hiemale* var. *mesodon*, *Synedra ulna* and *Nitzschia* spp. were present in the Birkenhead River downstream of the effluent discharge when sampled on 26 June 1979, during fish rearing operations. *Ulothrix zonata* and *U. tenuissima* were moderately abundant in the effluent channel.

SNOOTLI CREEK (BELLA COOLA HATCHERY)

Water Chemistry

Influent and effluent waters at the Bella Coola Hatchery were slightly acidic (pH 6.6 to 7.1), with low hardness (10 to 13 $mg \cdot L^{-1}$ $CaCO_3$). From March to June 1979, water temperatures ranged from 4 to 6°C. Chemical composition is described in Table

27. Concentrations of total phosphate ranged from less than 2, to 5 ug·L^{-1}, ammonia from less than 2, to 13 ug·L^{-1}, and nitrate from 180 to 300 ug·L^{-1} (Table 28). The N:P ratio was 12:1 in the influent water.

The biomass of fish in the hatchery increased from 0.2 to 126 kg between March and June. Food was provided at rates of 40 kg·d^{-1} in March to 480 kg·d^{-1} in June.

Periphyton

Periphyton accumulations on natural substrates in Snootli Creek and its tributary receiving hatchery effluent were sampled on 12 June 1979. The green algae *Ulothrix zonata* and *U. cylindricum* were abundant in the tributary. Periphyton accumulation in Snootli Creek was greater immediately downstream of the tributary than upstream or further downstream. Small amounts of *Ulothrix* spp., the chrysophyte *Hydrurus foetidus*, and the blue-green alga *Phormidium autumnale* were present in Snootli Creek.

CHILLIWACK RIVER

Water Chemistry

Chilliwack River water was slightly basic (pH 7.2 to 7.6), with low hardness (13 to 32 mg·L^{-1} $CaCO_3$) from August 1978 to March 1980. Chemical characteristics are described in Table 31. Concentrations of total phosphate ranged from 2 to 20 ug·L^{-1}, ammonia from less than the detection limit (2 ug·L^{-1}) to 11 ug·L^{-1}, and nitrate from 59 to 170 ug·L^{-1} (Fig. 46). The mean annual N:P ratio was 21:1.

Periphyton

Mean annual chlorophyll *a* concentrations on artificial substrates were 6.9 ± 13.2 mg·m^{-2} in pools, and 3.1 ± 8.0 mg·m^{-2} in riffles. Biomass accumulations frequently were reduced during high river flows. The growing season was from late summer to mid-winter (Fig. 47a, 47b), with maximum chlorophyll *a* concentrations (50 mg·m^{-2}) in February and November 1979.

Ulothrix spp. (*U. zonata*, *U. tenuissima*) were the predominant algae in the February and November peaks (Fig. 48). *A. minutissima* was the predominant diatom throughout the year and

Hannaea arcus, *Gomphonema olivaceoides*, *Diatoma hiemale* var. *mesodon*, and *Synedra ulna* were common (Fig. 49). The chrysophyte *Hydrurus foetidus* was common in spring, and the xanthophyte *Vaucheria* sp. in early summer.

NICOLA RIVER

Water Chemistry

Nicola River water was basic (pH to 7.7 to 8.9) and relatively hard (51 to 138 mg·L^{-1} $CaCO_3$) from September 1978 to October 1979. Chemical composition is described in Table 31. Concentrations of total phosphate ranged from 36 to 99 ug·L^{-1}, except during February (635 ug·L^{-1}); ammonia from below detection (2 ug·L^{-1}) to 140 ug·L^{-1}, except during February (470 ug·L^{-1}); and nitrate from 8 to 170 ug·L^{-1} (Fig. 50). The mean annual N:P ratio was 1.4:1.

Periphyton

Mean annual chlorophyll *a* concentrations on artificial substrates were 15.8 ± 20.8 mg·m^{-2} in "slow riffles" (20 - 40 cm·sec^{-1}) and 25.5 ± 45.7 mg·m^{-2} in "fast riffles" (40 - 60 cm·sec^{-1}). No pool areas were present. The growing season was from August to October 1979 (Fig. 51) with a September peak of 140 mg·m^{-2} chlorophyll *a*.

During the growing season, there were thick diatom accumulations predominated by *Nitzschia kuetzingiana* and *Ni*. cf. *fonticola*. The diatoms *Navicula radiosa* var. *tenella*, *Na. salinarum* var. *intermedia*, *Na. tripunctata*, *Diatoma vulgare*, *A. minutissima*, *Epithemia sorex*, and the green algae *Draparnaldia plumosa*, *Stigeoclonium stagnatile* and *Oedogonium* spp. were common (Fig. 52, 53). On natural substrates, a thick (1 cm) diatom mat composed of *D. vulgare*, *Nitzschia* spp. and *Navicula* spp. developed.

During winter and spring, the diatoms *A. minutissima*, *Synedra rumpens*, *Gomphonema angustatum*, *Ni. kuetzingiana*, *Na. pelliculosa* and *Cocconeis placentula* were found. The chrysophyte *Hydrurus foetidus* was prediminant in early spring and the green alga *Ulothrix zonata* was predominant in early summer.

DEADMAN RIVER

Water Chemistry

Deadman River water was basic (pH 7.8 to 8.2), with moderate hardness (62 to 113 $mg\cdot L^{-1}$ $CaCO_3$) from November 1978 to August 1979. Chemical composition is described in Table 31. Concentrations of total phosphate ranged from 12 to 22 $ug\cdot L^{-1}$, ammonia from below detection (2 $ug\cdot L^{-1}$) to 11 $ug\cdot L^{-1}$, and nitrate from 17 to 240 $ug\cdot L^{-1}$ (Fig. 54). The mean annual N:P ratio was 4.4:1.

Periphyton

Mean annual chlorophyll *a* accumulations on artificial substrates were 4.0 ± 4.4 $mg\cdot m^{-2}$ in pools and 2.8 ± 6.3 $mg\cdot m^{-2}$ in riffles. The growing season was from May to August 1979 (Fig. 55a, 55b), with maximum chlorophyll *a* concentrations in pools in June (13 $mg\cdot m^{-2}$) and in riffles in August (20 $mg\cdot m^{-2}$).

During the growing season, the diatoms *Achnanthes minutissima*, *Cocconeis placentula*, *Nitzschia palea* and *Ni. kuetzingiana* were predominant on artificial substrates (Fig. 56, 57). *Synedra rumpens* and *Gomphonema* spp. (*G. angustatum*, *G. clevei*, *G. parvulum*) were common during summer and *G. olivaceoides* and *Fragilaria vaucheriae* were common during winter and spring.

Species typical of lake phytoplankton occasionally were abundant in the Deadman River. During autumn 1978, the blue-green alga *Aphanizomenon flos-aquae* and the diatoms *Fragilaria crotonensis* and *Asterionella formosa* were abundant on natural and artificial substrates. In mid-winter 1978, the chrysoflagellate *Ochromonas* sp. was common in stream water.

EAGLE RIVER

Water Chemistry

The Eagle River and its tributary, Crazy Creek, were sampled in March, April, September, and November 1980. Waters were slightly basic (pH 7.1 to 8.0) with low hardness (15 to 41 $mg\cdot L^{-1}$ $CaCO_3$). Chemical characteristics are described in Table 31. Concentrations of total phosphate ranged from the detection limit (2 $ug\cdot L^{-1}$) to 8 $ug\cdot L^{-1}$, ammonia from 2 to 10 $ug\cdot L^{-1}$, and nitrate from 86 to 250 $ug\cdot L^{-1}$. The mean N:P ratio was 36:1 in the Eagle River and 53:1 in Crazy Creek.

Periphyton

Periphyton accumulations were low in March and April 1980 on natural substrates. Maximum accumulations occurred in August and November, with greater accumulations in the Eagle River than in Crazy Creek. In both streams, the diatoms *Didymosphenia geminata*, *Achnanthes minutissima* and *Hannaea arcus* were present on all sampling dates. The predominant species were the chrysophyte *Hydrurus foetidus* during March and April and the green algae *Stigeoclonium stagnatile* and *Ulothrix zonata* during August and November. In addition, the diatoms *Synedra ulna*, *Fragilaria construens*, *F. vaucheriae*, and *Gomphonema* spp. were common in the Eagle River.

Diatom numbers on artificial substrates were much greater in the Eagle River than in Crazy Creek in March 1980. *H. arcus* and *A. minutissima* were predominant in riffles of both streams. *Hydrurus foetidus* was abundant in Crazy Creek. In the pool sample from the Eagle River, *A. minutissima* was predominant and *H. arcus*, *F. construens*, and *Ulothrix subconstricta* were common.

Benthic Invertebrates

A mean of 37,700 organisms$\cdot m^{-2}$ was collected at the single site in the Eagle River in April 1980. Diptera (principally Chironomidae) were predominant and Plecoptera, Trichoptera, and Ephemeroptera were common (Table 32). The chironomids *Micropsectra* and *Rheotanytarsus* were the most abundant genera and *Microtendipes*, *Stempellinella* and *Cricotopus* were common. The diversity index was 3.2.

FINN CREEK

Water Chemistry

Finn Creek water was neutral (pH 6.7 to 7.2) and low in hardness (10 to 19 $mg\cdot L^{-1}$ $CaCO_3$) in March, April, September and November 1980. Chemical composition is described in Table 31. Concentrations of total phosphate ranged from below detection (2 $ug\cdot L^{-1}$) to 3 $ug\cdot L^{-1}$, ammonia from 3 to 6 $ug\cdot L^{-1}$, and nitrate from 103 to 155 $ug\cdot L^{-1}$. The mean N:P ratio was 20:1.

Periphyton

Periphyton accumulations were small on natural substrates, and consisted of the diatoms *Hannaea arcus*, *Achnanthes* minutissima, and Gomphonema spp. The green algae Spirogyra spp. were present during autumn and Oedogonium spp. were present during spring.

Benthic Invertebrates

A mean of 51,800 organisms$\cdot$m^{-2} was collected at the single site in Finn Creek in April 1980. Ephemeroptera, Plecoptera, and Trichoptera (grouped together) were predominant and Diptera (mainly Chironomidae) were common (Table 32). Unidentified Heptageniidae (Ephemeroptera) were the most abundant organisms. The diversity index was 1.3.

OTHER RIVERS

Periphyton and water were sampled in several streams (Table 2) during surveys of potential hatchery sites. Periphyton species and abundance are described in Appendix I. Periphyton accumulations frequently were small at the time of sampling. However, the Bowron sidechannel and the Raft and Cheakamus Rivers had moderate to heavy accumulations of diatoms and green algae during autumn and the Little Nitinat River had moderate accumulations during spring.

COMPARISONS AMONG STREAMS

Water Chemistry

Concentrations of most chemical constituents were similar upstream and downstream of the hatcheries. However, ammonia and total phosphate concentrations increased significantly downstream of the Quinsam, Puntledge, Big Qualicum and Capilano hatcheries during periods of maximum periphyton abundance. Concentrations were highest immediately downstream of hatcheries and decreased further downstream, frequently to concentrations similar to those at control sites. The same trends for ammonia and total phosphate concentrations were found in the Conuma River and Inches, Loon, and Snootli Creeks during spring sampling periods.

Total Phosphate Concentrations: Total phosphate concentrations were higher downstream of hatcheries than upstream during the periphyton growing seasons (Fig. 58a), except in the Capilano and Conuma Rivers. Mean total phosphate concentrations in the streams were ranked as follows:

high (80-115 $ug \cdot L^{-1}$) - Nicola River and Loon Creek
moderate (15-40 $ug \cdot L^{-1}$) - sites downstream of the Big Qualicum, Quinsam, and Inches hatcheries
low (2-15 $ug \cdot L^{-1}$) - Capilano, Puntledge, Conuma, Chilliwack and Eagle Rivers; Snootli, Finn and Crazy Creeks; sites upstream of the Big Qualicum, Quinsam and Inches hatcheries.

Ammonia Concentrations: Ammonia concentrations were higher downstream of hatcheries than upstream during periphyton growing seasons (Fig. 58b). Mean ammonia concentrations in the streams were ranked as follows:

moderate (15-40 $ug \cdot L^{-1}$) - sites downstream of the Quinsam, Big Qualicum, Inches, and Loon hatcheries; Nicola River
low (2-15 $ug \cdot L^{-1}$) - Puntledge, Capilano, Conuma, Deadman, Chilliwack and Eagle Rivers; Snootli, Crazy, and Finn Creeks; sites upstream of the Quinsam, Big Qualicum, Inches, and Loon hatcheries

Nitrate Concentrations: Nitrate concentrations at all sites within a stream were similar during the periphyton growing seasons (Fig. 58c). Mean nitrate concentrations in the streams were ranked as follows:

high (350-450 $ug \cdot L^{-1}$) - Inches Creek
moderate (100-160 $ug \cdot L^{-1}$) - Capilano, Chilliwack, and Eagle Rivers; Crazy, Finn, and Loon Creeks
low (20-75 $ug \cdot L^{-1}$) - Quinsam, Puntledge, Big Qualicum, Deadman, Conuma and Nicola Rivers; Snootli Creek.

Hatchery Nutrient Loadings: Effluent ammonia loadings at the Quinsam, Puntledge, Big Qualicum, and Capilano hatcheries ranged from 0.1 to 15.9 $kg \cdot d^{-1}$ and total phosphate loadings ranged from 0.1 to 7.1 $kg \cdot d^{-1}$ (Fig. 59). Loadings were greatest during spring, at the time of maximum feeding rates in the hatcheries. The loadings were not related mathematically to rates of food supplied or fish biomass at the hatcheries (linear and non-linear regression, $P<0.05$). Mean effluent phosphate and ammonia loadings, fish biomass reared and daily rates of food supplied were much higher at the Big Qualicum and Quinsam hatcheries than at the Puntledge and Capilano hatcheries (Table 33).

Periphyton Biomass Accumulation

Mean chlorophyll a concentrations and organic weights on artificial substrates were significantly greater immediately downstream of hatchery discharges (60-120 m downstream) than upstream in the Quinsam, Puntledge, and Capilano Rivers and Loon Creek. Biomass decreased progressively downstream of hatcheries, except in the Capilano and Big Qualicum Rivers. Biomass was very low in the Conuma River during spring, with similar levels at all sites. In the Big Qualicum River and Inches Creek, heavy accumulations of filamentous algae downstream of the hatchery discharges drifted onto artificial substrates, resulting in insufficient data for those streams. Periphyton accumulations on natural substrates were higher downstream of hatchery discharges than upstream in all streams studied. Periphyton accumulations were small in the Chilliwack and Deadman Rivers and very large in the Nicola River.

Seasonal Variation: Peak periphyton accumulations were measured during spring in the Puntledge River and Inches Creek; during summer in the Big Qualicum, Capilano, and Deadman Rivers; during autumn in the Quinsam, Nicola, and Eagle Rivers and Loon, Crazy, and Finn Creeks; and during winter in the Chilliwack River. There were variations in timing of smaller peaks among sites in each stream.

Annual Integrated Biomass Accumulations: Annual estimates of chlorophyll *a* and organic weight accumulations were obtained by integrating, by calculus, data collected over one year from the Quinsam, Puntledge, Big Qualicum, and Capilano Rivers (Fig. 60a, 60b). At control sites, periphyton chlorophyll *a* was greatest in riffles of the Big Qualicum River (1.5 $g \cdot m^{-2} \cdot yr^{-1}$) and pools of the Quinsam River (2.0 $g \cdot m^{-2} \cdot yr^{-1}$) and smallest in pools and riffles of the Puntledge and Capilano Rivers (0.1-0.2 $g \cdot m^{-2} \cdot yr^{-1}$). Accumulations increased greatly immediately downstream of hatchery discharges, and decreased further downstream, except in the Capilano River. Accumulations downstream of the hatcheries were greatest in pools at site 2 of the Puntledge River (13 $g \cdot m^{-2} \cdot yr^{-1}$).

Autotrophic Index: The mean annual autotrophic index ranged from 150 to 1,100 for the Quinsam, Puntledge, Big Qualicum, and Capilano Rivers (Fig. 61). In pools, the index decreased between control (700 to 1,100) and downstream sites (350 to 640). In riffles, the index ranged from 150 to 900, with no consistent trends among sites.

Statistical Correlations of Nutrient and Chlorophyll a Concentrations: In the Quinsam River, there was a positive linear correlation between concentrations of chlorophyll *a* and nitrogenous compounds (nitrate, ammonia, organic nitrogen) at sites 2, 3, and 4, and at the four sites analyzed together (Table 34). Chlorophyll *a* concentrations were influenced by phosphate and nitrogen together in the multiple regression analyses at sites 2, 3, and 4, and at all sites analyzed together (Table 35).

In the Puntledge River, there was a negative linear correlation between total phosphate and chlorophyll *a* concentrations, considering all sites together on an annual basis, but not during spring alone (Table 34). Multiple regression analyses indicated that chlorophyll *a* concentrations were influenced by interactions of nitrate concentrations and flow over substrates at sites 1 and 2, and additionally by phosphate at site 2 (Table 35).

In the Big Qualicum River, chlorophyll *a* data from sites 4, 5, and 6 were not analyzed because of drift *Cladophora* coverage. There was a negative linear correlation between nitrate and chlorophyll *a* concentrations at sites 2 and 3 (Table 34). In multiple regression analyses, chlorophyll *a* concentrations were influenced by interactions of nitrate and ammonia concentrations at site 2 (Table 35).

In the Capilano River, there were linear correlations between chlorophyll *a* and phosphate, ammonia, and silica concentrations at all sites analyzed together, but not at individual sites (Table 34). In multiple regression, concentrations of silica and organic nitrogen interacted to influence chlorophyll *a* concentrations at all sites considered together (Table 35).

Periphyton Species Composition

Periphyton species composition differed upstream and downstream of hatchery discharges in all streams, especially during periods of peak accumulation. In each stream, sites downstream of the hatchery were similar in composition, but they differed from the upstream site. The upstream site was more similar to the site furthest downstream than to sites closer to the hatchery. Diatoms and green algae were the most abundant periphyton in the streams.

Diatoms: The diatom *Achnanthes minutissima* was the most abundant diatom on artificial substrates in pools and riffles in most streams. It was predominant year-round at most sites, and abundance seldom differed substantially among sites in a stream. *Nitzschia* spp. were the predominant diatoms in periphyton peaks in pools and riffles immediately downstream of the Quinsam, Puntledge and Loon Hatcheries, and were common immediately downstream of other hatcheries. The most abundant *Nitzschia* spp. were *Ni*. *palea*, *Ni*. cf. *fonticola*, *Ni*. *kuetzingiana*, and *Nitzschia* sp. *Navicula pelliculosa* was predominant in riffles downstream of hatchery discharges, in association with *Nitzschia* spp., in the Quinsam, Big Qualicum, and Nicola Rivers and Loon Creek.

The common diatoms in the Quinsam, Puntledge, Big Qualicum and Capilano Rivers were *Synedra rumpens*, *S*. *ulna*, *Hannaea arcus*, *Diatoma hiemale* var. *mesodon*, *Fragilaria vaucheriae*, *Achnanthes linearis* var. *pusilla*, *Cymbella minuta*, *C*. *minuta* var. *silesiaca*, *Gomphonema angustatum*, and *G*. *parvulum* (Table 36). These species were common in many other streams. In addition, *Didymosphenia geminanta* was common on natural substrates in the Eagle River and Crazy Creek and *Achnanthes gibberula* was predominant in Hixon Creek. Many species were more abundant downstream of the hatcheries than upstream.

Green Algae: *Ulothrix* spp. (*U*. *zonata*, *U*. *tenuissima*) were predominant or common in the periphyton peaks on artificial substrates in the Quinsam, Puntledge, Big Qualicum, Capilano, Conuma, and Chilliwack Rivers (Table 36). Accumulations usually were greatest immediately downstream of hatchery discharges. *Ulothrix* spp. also were abundant on natural substrates in the streams and in hatchery rearing and effluent channels. *Stigeoclonium stagnatile*, *Draparnaldia plumosa*, and *Ulothrix* *tenerrima* were common in many streams. *Cladophora glomerata* was common in the Big Qualicum River, and predominant in Big Qualicum Hatchery rearing channels. *Oedogonium* spp., *Bulbochaete* cf. *furberae*, *Mougeotia* spp., *Spirogyra* spp., *Zygnema* spp., and *Geminella minor* were common in the Puntledge and Capilano Rivers. *Rhizoclonium hieroglyphicum* was common on natural substrates in Loon Creek downstream of the hatchery.

Other Algae: The blue-green algae *Phormidium autumnale*, *Plectonema notatum*, and *Lyngbya digueti* were more abundant downstream of the Quinsam, Puntledge, Big Qualicum, and Capilano hatcheries than upstream on both artificial and natural substrates (Table 36). The xanthophyte *Tribonema utriculosum* was abundant on natural substrates in Inches Creek downstream of the rearing area. The chrysophyte *Hydrurus foetidus* was common during spring downstream of the Capilano, Puntledge and Conuma hatcheries and in the Eagle River and Hixon, Loon, Snootli and Crazy Creeks on artificial and natural substrates.

Similarities Among Rivers: The Puntledge and Capilano Rivers were most similar in diatom species composition (similarity index for pools = 0.84, for riffles = 0.72; mean of all sites). The Quinsam and Puntledge Rivers were moderately similar (pools = 0.68, riffles = 0.55). The Big Qualicum River (riffles only) was similar to the Quinsam River (0.69), but not to the Puntledge (0.36) or Capilano (0.29) Rivers.

Individual sites in the Capilano, Puntledge and Quinsam Rivers were very similar in composition, except for sites immediately downstream of the Capilano and Quinsam hatcheries (Table 37). Big Qualicum River sites were similar to sites downstream of the Quinsam Hatchery.

Considering control sites, species composition at site 1 in the Puntledge River was not similar to any other site or stream (Table 37) and was located in the Puntledge Hatchery spawning channel. Site 1 in the Big Qualicum River was similar to sites downstream of the Quinsam Hatchery. Site 1 in the Capilano River was similar to site 1 in the Quinsam River and sites 2, 3, and 4 in the Puntledge River. Site 1 in the Quinsam River was similar to sites in the Capilano and Puntledge Rivers.

Species Diversity: Species diversity of diatom assemblages in the Quinsam, Puntledge, Big Qualicum, and Capilano Rivers ranged from 1.5 to 2.0 in pools, and from 1.2 to 1.8 in riffles. Differences among sites and streams usually were small; however, diversity often was greatest immediately downstream of the hatcheries.

Benthic Invertebrate Abundance

Benthic invertebrates were significantly more abundant downstream of hatcheries than upstream (Fig. 62). Maximum abundance was recorded at sites 60 to 700 m downstream of the discharges: site 2 or 3 in the Quinsam, Puntledge, and Conuma Rivers and Loon Creek; and site 4 or 6 in the Big Qualicum River. In the Capilano River, highest numbers were found at site 4, 2,300 m downstream of the effluent discharge. Maximum numbers ranged from 6000 organisms$\cdot$m^{-2} in the Conuma River to 226,000 organisms$\cdot$m^{-2} in the Big Qualicum River.

Benthic invertebrates were most abundant during seasons of maximum periphyton accumulation: the end of summer in the Quinsam and Big Qualicum Rivers, and spring in the Puntledge River. Other streams were sampled only once.

Considering sites upstream of hatchery discharges, invertebrate abundance was highest in the Big Qualicum River, intermediate in the Quinsam River, and lowest in the Puntledge, Capilano, and Conuma Rivers and Loon Creek (a range of 2,000 to 77,000 organisms$\cdot$m^{-2}) (Fig. 62). A similar ranking of abundance among streams occurred at sites downstream of the discharges. The Big Qualicum and Puntledge Rivers had very large increases in abundance at sites downstream of hatchery discharges relative to upstream sites.

Benthic Invertebrate Composition

Adjacent sites downstream of hatchery discharges were most similar in composition and sites upstream and immediately downstream of discharges were least similar. The upstream and furthest downstream sites were relatively similar, reflecting a gradual return to species composition found at upstream sites. Diversity of the samples ranged from 2.5 to 4.2, with no trends among sites in the streams.

Chironomidae: The predominant invertebrates in all streams except Finn Creek were Chironomidae, primarily Orthocladinae and Chironominae. They were more abundant downstream of hatchery discharges, than upstream, with highest numbers found downstream of the Big Qualicum Hatchery.

Cricotopus was predominant (20-50% of total invertebrate numbers) in the Puntledge, Big Qualicum, and Capilano Rivers and Loon Creek, and common in the Quinsam, Conuma and Eagle Rivers. Other predominant genera included *Eukiefferiella*, *Micropsectra*, and *Rheotanytarsus*. Common genera (10-20%) included *Corynoneura*, *Heterotrissocladius*, *Microtendipes*, *Polypedilum*, *Rheocricotopus*, *Stempellinella*, and *Thienemanniella*. These species are common in other Vancouver Island streams (H. Mundie, personal communication). Most chironomids, including *Cricotopus*, *Micropsectra*, and *Eukiefferiella*, were more abundant downstream of the discharges than upstream. However, *Stempellinella* and *Rheotanytarsus* were least abundant immediately downstream of the Big Qualicum and Quinsam hatcheries, respectively.

Ephemeroptera, Plecoptera, and Trichoptera: These insects were common in all streams. Similar numbers were found at all sites within a stream except for the Puntledge River, where numbers were lower at the upstream site than at downstream sites. They were most abundant, and predominant, during spring at sites 2, 3, and 4 in the Puntledge River and in Finn Creek. They ranked second in abundance, after Chironomidae, in the Big Qualicum River upstream of the hatchery, in the Conuma River and in Loon Creek. These orders were common (10-20% abundance) in the Big Qualicum (at downstream sites), Quinsam, Capilano, and Eagle Rivers.

Ephemeroptera were the most abundant of the three orders in all streams except Loon Creek, where Trichoptera were most abundant. The most abundant Ephemeroptera species in the various streams were *Ameletus* sp. (Siphlonuridae), *Baetis* spp. (Baetidae), *Cinygmula* sp. (Heptageniidae), *Ephemerella inermis* (Ephemerellidae), *Pseudocloeon* sp. (Baetidae), and unidentified Heptageniidae. Chloroperlidae and other, unidentified families of Plecoptera occurred upstream of the Quinsam and Big Qualicum hatcheries and in the Conuma and Puntledge Rivers. The most abundant Trichoptera were *Cheumatopsyche* sp. and *Hydropsyche* sp. (Hydropsychidae) in the Puntledge River, and *Anagapetus* sp. (Glossosomatidae) and Limnephilidae in Loon Creek.

Oligochaeta: Oligochaetes were most abundant immediately downstream of the Quinsam and Big Qualicum hatcheries, where they were the predominant invertebrates. They were common in the other streams, where numbers were similar upstream and downstream of the discharges. The naidid oligochaetes *Nais* spp. and *N. elinguis*, and *N. communis* were common in the Quinsam and Big Qualicum Rivers. Naidid, enchytraeid, and lumbriculid oligochaetes occurred in the Puntledge River. The tubificid *Limnodrilus hoffmeisteri* was abundant in the Big Qualicum Hatchery rearing channels.

Other Benthic Invertebrates: Ostracoda were common in the Big Qualicum, Quinsam and Puntledge Rivers at sites away from the influence of hatchery discharges. Harpacticoid copepods were common at certain sites in the Big Qualicum and Quinsam Rivers. Hydracarina were common in the Quinsam, Puntledge, Big Qualicum and Capilano Rivers downstream, but not immediately downstream, of hatchery discharges.

DISCUSSION

RECEIVING WATER AND EFFLUENT CHEMISTRY

Ammonia and total phosphate concentrations were statistically higher downstream of hatchery discharges than upstream. The greatest differences among sites were measured during late spring and summer, the period of maximum periphyton accumulation in most streams. Nutrient concentrations were highest immediately downstream of the hatcheries (60-120 m), but decreased further downstream.

The very low phosphate concentrations (2 to 4 $\mu g \cdot L^{-1}$) measured upstream of most hatchery discharges were similar to concentrations measured in Carnation and Ritherdon Creeks by Shortreed and Stockner (1983). The authors classified these two coastal B.C. streams as highly oligotrophic. However, relatively high phosphate concentrations were measured upstream of hatcheries in the Big Qualicum and Quinsam Rivers and Loon and Inches Creeks as well as downstream of all hatcheries in the present study.

Concentrations of most other chemical constituents were similar upstream and downstream of the hatcheries. Most constituents were not affected by fish rearing operations, because of their biologically conservative nature. These included pH, alkalinity, conductivity, and major anions and cations. However, nitrate and organic and particulate carbon and nitrogen concentrations, and turbidity levels also were statistically similar upstream and downstream of most hatcheries. Particulate matter may have settled in effluent channels or in the streams in areas between the discharges and the first sites sampled downstream. For most parameters, seasonal variations were greater than the variations among sites.

Hatchery effluents contained much higher concentrations of total phosphate and ammonia than did the receiving streams and, hence, hatcheries were the major source of nutrient addition to the streams. The rearing and effluent channels provided areas for deposition of particulate matter, decomposition of hatchery wastes, regeneration of nutrients and reduction in BOD, as has been reported for many other hatcheries (Nakatani et al. 1974; Underwood McLellan Ltd. 1979a) Decaying salmon carcasses in streams also contributed unmeasured amounts of phosphorus and nitrogen during autumn and winter.

Substantial daily loadings of phosphate and ammonia were measured in effluents of the Quinsam, Puntledge, Big Qualicum, and Capilano hatcheries. Loadings were greatest during spring, at the time of maximum feeding rates and fish biomass in the hatcheries. However, effluent nutrient loadings remained high during early summer, following release of fish and reduction of fish feeding rates. This suggests that hatchery wastes settled out in the channels, decomposed, and released nutrients for some time following fish release.

Mean effluent nutrient loadings, fish biomass reared, and daily fish feeding rates were higher at the Quinsam and Big Qualicum hatcheries than at the Puntledge and Capilano hatcheries. However, fish feeding rates were greater, and effluent nutrient loadings were smaller, at the Quinsam than at the Big Qualicum Hatchery and, similarly, at the Capilano than at the Puntledge Hatchery. This anomaly may have been related to the use of gravel rearing channels at the Puntledge and Big Qualicum hatcheries, because the channels were cleaned less often and less efficiently than were concrete channels. Underwood McLellan Ltd. (1979a) also noted differences in effluent quality between effluents from concrete and earthen channels. The effluent clarifier at the Quinsam Hatchery probably helped reduce effluent nutrient loadings. The Capilano Hatchery effluent treatment facility was not operated during the study.

PERIPHYTON

Biomass Accumulation

Chlorophyll _a_ and organic accumulations on artificial substrates were statistically greater downstream of hatcheries than upstream. In several American streams, moderate to large increases in periphyton accumulations were measured downstream of hatchery discharges, with the extent of the periphyton response dependent on the rate of food supply in the hatcheries (Liao and Mayo 1970; Nakatani _et al_. 1973; Ball and Kevern 1973).

The effects of nutrient enrichment were localized, with greatest periphyton accumulations measured immediately downstream of hatchery discharges (60 to 120m). Accumulations decreased further downstream of most hatcheries, except for the Big Qualicum and Capilano hatcheries. In the Big Qualicum River, this could be attributed to the short distance of river (600 m) between hatchery and tidal influence. In the Capilano River, there was better exposure to sunlight and a more moderate stream flow regime at the site furthest downstream (2300 m) than at the other sites, which were located in a canyon.

Considering upstream, or control sites, the Puntledge, Capilano, and Conuma Rivers had very low levels of chlorophyll _a_ and phosphate, comparable to values reported for the highly oligotrophic Carnation and Ritherdon Creeks, (Stockner and

Shortreed 1976). Higher chlorophyll a and nutrient concentrations were measured at upstream sites in the Quinsam and Big Qualicum Rivers, and at most sites downstream of hatchery discharges. This reflected greater productivity, either naturally or in response to hatchery nutrient discharges.

The autotrophic index, the ratio of periphyton organic weight to chlorophyll a, has been used to assess the periphyton composition with respect to organic pollution (Collins and Weber 1978). The index usually is high (400 to 1000) downstream of organic effluent discharges where periphyton contain much organic matter and bacteria, and low in undisturbed and unpolluted habitats. However, the reverse was found for pool areas of the Quinsam, Puntledge, Big Qualicum and Capilano Rivers, where there were much higher values of the autotrophic index upstream of hatchery discharges than downstream. Riffle areas showed no consistent trends. The high values of the index at upstream sites reflected rather low chlorophyll a and moderate detritus accumulations indicative of oligotrophic rather than eutrophic conditions in these streams.

The nutrient most likely to limit algal growth has been predicted by the ratio of dissolved inorganic nitrogen to phosphorus, the N:P ratio (Miller et al. 1978). Many algae have a cellular N:P ratio of about 12:1; hence, a similar ratio in the environment is considered optimal for growth. Ratios much higher than 12:1 suggest phosphorus limitation of the algae, whereas ratios much less than 12:1 suggest nitrogen limitation. In the streams studied, N:P ratios decreased downstream of hatchery discharges, reflecting the relative importance of phosphate over ammonia (nitrogen) additions from the effluents in the calculation of the ratio. Ratios increased further downstream, as ammonia and phosphate concentrations decreased to levels similar to those upstream of the discharges. Streams with high N:P ratios (13:1 to 63:1) and, presumably, phosphorus limitation, included the Puntledge, Capilano, Conuma, Chilliwack, and Eagle Rivers and Inches, Crazy, and Finn Creeks. Very low total phosphate concentrations and periphyton accumulations were measured at all sites in these streams, except for Inches Creek. Streams with low N:P ratios (1.4:1 to 8.4:1) and, presumably, nitrogen limitation, included the Quinsam, Big Qualicum, Deadman and Nicola Rivers and Loon Creek. Total phosphate concentrations and periphyton accumulations usually were considerably higher in streams with low N:P ratios than in those with high ratios. However, nitrogen concentrations were somewhat similar in most streams studied.

Seasonal Variations: River velocity, flood frequency, light regime (intensity, daylength, site exposure), and temperature, as well as nutrient concentrations, regulate the seasonal growth patterns of periphyton (Whitton 1979). In most streams, periphyton accumulations are low during winter because of low light levels, low temperatures, and high stream flows. Higher temperatures and light levels and lower, more constant flow permit faster growth and accumulation during spring, summer, and autumn. Peak periphyton accumulations were measured in spring, summer, autumn, and winter in the various streams studied.

Most streams studied had good exposure to sunlight. However, reduced light penetration to the streambed may have reduced periphyton growth rates in some streams relative to the unshaded streams. The Quinsam and Deadman Rivers were heavily shaded by deciduous trees and the Capilano River was situated in a steep-walled canyon. Parker et al. (1973) and Shortreed and Stockner (1983) reported differences in periphyton biomass and species composition between shaded and unshaded areas of other streams.

Stream velocity affects growth rates, accumulation rates, and species composition of the periphyton (Whitford 1960). Although moderate water velocities usually stimulate periphyton growth rates (Horner and Welch 1981), the high velocities and scouring which accompany flooding severely reduce rates of growth and accumulation (Tett et al. 1978). Scouring and freshets occur frequently in coastal B.C. streams.

The regulation of stream flows by dams in the Quinsam, Puntledge, and Big Qualicum Rivers resulted in moderate and constant flows during the periphyton growing seasons which encouraged periphyton accumulations. In contrast, water release from the reservoir on the Capilano River resulted in frequent unpredictable floods and scouring of periphyton accumulations throughout the year.

Flows in the unregulated streams in central B.C., such as the Nicola and Eagle Rivers and Loon, Crazy, and Finn Creeks, were affected by different climatic conditions than were coastal streams. Highest stream flows occurred in late spring, following snow melt; low flows occurred during the remainder of the year because of low rainfall. The flow regime favoured maximum periphyton accumulations during late summer and early autumn. However, the Thompson River, a much larger central B.C. stream, had peak accumulations in winter (Langer and Nassichuk 1975).

Periphyton Species Composition and Ecology

Species composition generally was similar on natural and artificial substrates, as has been reported in many other studies (Whitton 1979; Weitzel 1979). Most species were reported previously in B.C. by Stein and Borden (1979), and occurred upstream and downstream of hatchery discharges.

The abundance of individual species differed upstream and downstream of hatchery discharges, especially during periods of peak biomass accumulations. In each stream, sites downstream of the hatchery were similar in composition. The site furthest downstream of the discharge was somewhat similar to the upstream site, reflecting some recovery from nutrient enrichment effects. Differences in species composition were found upstream and downstream of hatchery discharges in two American streams (Ball and Kevern 1973; Bahls and Bahls 1974).

The green algae *Ulothrix* spp. (*U. zonata*, *U. tenuissima*) predominated in the seasonal periphyton peaks in most streams. *Ulothrix* spp. were abundant in pools and riffles, upstream and downstream of hatchery discharges, and at any time of the year. *Ulothrix* spp. responded positively to increased nutrient concentrations, with greatest accumulations immediately downstream of hatchery discharges. Because *U. zonata* has been reported from oligotrophic, eutrophic, and polluted streams, two ecological races (clean and polluted water) were proposed by Fjerdingstad (1965). *U. tenuissima* has been reported mainly from unpolluted habitats (Sl decek 1973).

The predominant diatom in most habitats was *Achnanthes minutissima*, a ubiquitous diatom (Lowe 1974). Upstream of many hatcheries, the most common diatoms included *Achnanthes* spp., *Synedra rumpens*, *Hannaea arcus*, and *Diatoma hiemale* var. *mesodon*. Similar species composition was found in the oligotrophic Carnation and Ritherdon Creeks (Stockner and Shortreed 1976).

Diatoms more typical of nutrient-rich conditions (Sl decek 1973; Lowe 1974) were abundant downstream of the discharges. The predominant species immediately downstream of the Big Qualicum, Quinsam and Loon hatcheries were *Nitzschia* spp. (*N. palea*, *N.* cf. *fonticola*, *N. kuetzingiana*, *Nitzschia* sp.) and *Navicula pelliculosa*. In other streams the most common species were *Achnanthes minutissima*, *Synedra ulna*, *Diatoma vulgare*, *Cocconeis placentula*, *Gomphonema angustatum*, *G. parvulum*, *Cymbella minuta* and *C. minuta* var. *silesiaca*.

The high abundance of the green alga *Cladophora glomerata* during summer in rearing channels of the Big Qualicum Hatchery probably was related to the high phosphate concentrations found there (15-64 $ug \cdot L^{-1}$). Although it was not abundant in the Big Qualicum River there were some nuisance effects of drifted algae originating in hatchery channels. *C. glomerata* has been reported as a nuisance alga in many streams containing high phosphorus concentrations (Pitcairn and Hawkes 1973).

Natural substrates in several streams had mats of the chrysophyte *Hydrurus foetidus* during spring and the blue-green alga *Phormidium autumnale* during summer. These species usually occurred in the more oligotrophic streams, with greatest abundance immediately downstream of the hatchery discharges. Although *H. foetidus* has been reported mainly from unpolluted mountain streams (Parker *et al.* 1973), *P. autumnale* has been reported mainly from nutrient rich streams (Palmer 1969).

Diversity: Species diversity is expected to decrease in nutrient-enriched and organically polluted habitats because sensitive species are eliminated and tolerant species become more abundant (Moss 1973). However, the Shannon-Weaver diversity index for diatoms was very low (1.2 to 2.0), with small differences among sites. The maximum diversity values immediately downstream of hatchery discharges suggested the reduction of a stress at those sites, probably the stress of naturally low background nutrient concentrations.

BENTHIC INVERTEBRATES

Abundance

Benthic invertebrates also were statistically more abundant downstream of hatchery discharges than upstream. This response to organic and nutrient enrichment has been well documented, although the response usually is indirect: through changes in food availability and through alterations of habitat (increased siltation, thick layers of periphyton on the substrate, and reduced dissolved oxygen concentrations in interstitial areas) (Gaufin 1973; Godfrey 1978; Hawkes 1979).

Benthic invertebrates were most abundant in samples taken at the end of the periphyton growing season (summer in the Quinsam and Big Qualicum Rivers, spring in the Puntledge River), reflecting the greater abundance of food. In the Puntledge and Capilano Rivers, benthic invertebrate abundance was affected by dams upstream of the study areas either because of site placement (in the Puntledge Hatchery spawning channel) or because of an unstable physical environment (frequent violent floods in the Capilano River).

Composition and Ecology

Invertebrates tolerant of organic enrichment, such as chironomids and naidid oligochaetes, increased in abundance downstream of many hatcheries. However, insects considered sensitive to enrichment, such as Ephemeroptera, Plecoptera and Trichoptera, had similar abundance upstream and downstream of the discharges. Oligochaetes are considered to reflect organic enrichment because they tolerate considerable oxygen depletion and eat bacteria (Brinkhurst and Cook 1974; Learner _et al._ 1978). Chironomids are considered reasonably tolerant of organic enrichment, but ecological requirements and pollution tolerances of many species are poorly defined (Roback 1974). Ephemeroptera, Plecoptera, and Trichoptera traditionally have been considered indicators of unpolluted water because of their requirement for high dissolved oxygen concentrations, but pollution tolerance of individual species vary (Gaufin 1973).

The primary food source was algae for most invertebrates, including many species of Chironomidae (Orthocladinae, Chironominae), Ephemeroptera, Plecoptera and Trichoptera (Roback 1974). Bacteria and algae were the main food of naidid oligochaetes (Brinkhurst and Cook 1974; Learner _et al._ 1978). Some carnivores were present, such as Hydracarina (Reid 1961) and some species of Chironomidae (Tanypodinae) and other insects. The other common orders of benthic invertebrates were omnivorous filter feeders (Ostracoda) or scrapers (Harpacticoida: Copepoda) (Wetzel 1975).

The predominant benthic invertebrates were herbivorous chironomids at almost all sites. Greatest abundance occurred downstream of hatchery discharges, where the large periphyton accumulations presumably provided ample food and habitat (Mundie 1974). The Big Qualicum River had the largest numbers of chironomids and accumulations of periphyton.

Naidid oligochaetes were predominant immediately downstream of the Quinsam Hatchery and common downstream of the Big Qualicum Hatchery. The increased abundance may have been related to the relatively high nutrient loads in the effluents and to bacterial accumulations in the streams. The bacterial sewage "fungus" _Sphaerotilus natans_ was observed in periphyton samples from natural and artificial substrates downstream of most hatcheries.

No statistically significant differences in abundance of Ephemeroptera, Plecoptera, and Trichoptera were found upstream and downstream of most hatchery discharges, reflecting the relatively good water quality in these streams. The exception was the Puntledge River, where very low numbers occurred at the control site located in the hatchery spawning channel.

Copepoda (Harpacticoida), Ostracoda, and Hydracarina were abundant downstream of hatchery discharges in some streams. Although food was more abundant downstream of the discharges, other factors may have affected distribution. Ecological requirements of these organisms are not well known (Reid 1961; Wetzel 1975).

Diversity: Benthic invertebrate diversity usually decreases in organically polluted areas, because pollution sensitive species are eliminated and pollution tolerant species become more abundant (Godfrey 1978). However, no obvious trends in the diversity index were found in these streams.

IMPLICATIONS FOR STREAM COMMUNITIES

The relatively small alterations to benthic communities in the Puntledge and Capilano Rivers reflected habitat enrichment, rather than degradation. Nutrient enrichment resulted in a moderate increase in periphyton accumulation and in abundance of benthic invertebrates easily utilized by fish. This moderate response to hatchery discharges was related to the low background levels of nutrients, periphyton, and benthic invertebrates, as well as the relatively small hatchery operations and effluent loadings of ammonia and phosphate.

The more substantial alterations to benthic communities in the Big Qualicum and Quinsam Rivers suggested some degradation of habitat downstream of hatchery discharges. This was most apparent in the Big Qualicum River, where dense periphyton mats had the potential to disrupt habitats of both invertebrates and fish. With respect to the greatly increased abundance of benthic invertebrates, chironomids would be more easily utilized by fish than oligochaetes. The strong response of benthic communities in the Big Qualicum and Quinsam Rivers was related to the higher background levels of nutrients, periphyton, and benthic invertebrates, in addition to the much larger hatchery operations and effluent nutrient loadings relative to the Capilano and Puntledge Rivers.

Symptoms of severe degradation or gross pollution were not found downstream of any hatcheries, and environmental conditions were suitable for fish production in the streams. Dissolved oxygen concentrations were high upstream and downstream of the discharges; small amounts of sewage fungus occasionally occurred downstream; abundance of pollution sensitive insects was similar upstream and downstream, and pollution tolerant tubificid oligochaetes were not found in the streams.

Resident fish populations were not studied in relation to hatchery discharges in this study. However, two potential consequences of increased benthic productivity to fish are increased abundance of food and decreased quality of habitat.

The diet of salmonid fry consists mainly of juvenile and adult Chironomidae, Simuliidae, Ephemeroptera, Plecoptera, and Trichotera (Mundie 1969). Although Oligochaeta may be consumed, their importance in the salmonid diet is not well documented (Popchenko 1971; Aarefjord et al. 1973). Salmonid fry prefer drifting insects to oligochaetes and insects in the substrate (Mundie 1969). Chironomids increased greatly in abundance in response to the increased periphyton accumulations downstream of the hatchery discharges.

Thick algal mats may disrupt the habitats of fish and benthic invertebrates by decreasing the transport of dissolved gases through the substrate, eliminating habitats of some invertebrates, and reducing dissolved oxygen concentrations during decomposition in backwaters (Mundie 1974). The largest accumulations of green algae (mainly Ulothrix spp.) in riffle areas occurred in the Big Qualicum River, for at least 0.6 km downstream of the hatchery. Ulothrix spp. occurred in other streams, with lower abundance than in the Big Qualicum River.

Some areas of concern are apparent despite the moderate response of most coastal streams studied to hatchery discharges. These concerns are associated with the relationships among background productivity and nutrient levels, size of hatchery operations, and nutrient loadings in the effluent. The response of the benthic community is related positively to all three factors. Hence hatchery practices may need to be modified in streams with high background nutrient concentrations or relatively large hatcheries. The most sensitive streams are likely those in central B.C., where nutrient concentrations are higher and stream flows more moderate than in coastal streams. The potential for moderate to large increases in productivity in response to nutrient enrichment was suggested by background data collected from the Nicola and Eagle Rivers and Loon Creek.

Potential guidelines regarding hatchery practices and effluent treatment should consider the impact of ammonia and phosphate discharged from the hatcheries during summer, long after the release of fish and decline in feeding rates, particularly in hatcheries using gravel channels. Adequate cleaning of gravel channels and diversion of cleaning wastes from the streams may be necessary. The impact of nutrient addition is likely to be greatest during summer, when physical factors are most favourable for periphyton growth.

ACKNOWLEDGEMENTS

The authors wish to thank Drs. I.K. Birtwell, J.H. Mundie, and J.G. Stockner for their helpful reviews of the report and advice during the project. The water chemistry program was directed by K.V. Masuda, the periphyton program by the senior author and the benthic invertebrate program by B. Piercey. Field and laboratory assistance was provided by M. Kotyk, G. Carlson, L. Jantz, and R. Williams. Statistical analyses were performed by D. Jeffries, Quantum Research Ltd., Vancouver.

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Table 1. Hydrographic and fish rearing information for the major streams sampled.

Stream	Drainage area (km^2)	Mean annual discharge ($m^3 \cdot s^{-1}$)	No. fish released annually (millions)	Species of fish reared[1]
Quinsam	280	8.9	1.7	CO,CN,ST
Puntledge	453	30.6	1.3	CO,CN,CM,PK,ST
Big Qualicum	148	4.3	54.1	CO,CM,CN,ST
Capilano	172	20.0	1.5	CO,CN,ST
Conuma	na[2]	na	1.8	CM,CN
Inches	groundwater	na	0.9	CM
Loon	na	na	na	TR
Hixon	20	3.9	0.3	CO,CN
Birkenhead	596	23.8	0.01	CN
Snootli	na	na	0.2	CM,CN
Chilliwack	645	36.7	none	
Nicola	7280	28.8	none	
Deadman	962	1.7	none	
Eagle	904	38.1	none	
Crazy	117	na	none	
Finn	na	na	none	

[1] Fish Species
CO = coho
CM = chum
CN = chinook
PK = pink
ST = steelhead
TR = other trout

[2] na = information not available

Table 2. Sampling periods for water chemistry and periphyton

Stream	Sampling period	Artificial substrates
Existing hatcheries		
Quinsam	Aug. 1978 to Oct. 1979	yes
Puntledge	Aug. 1978 to Jul. 1980	yes
Big Qualicum	Aug. 1978 to Oct. 1979	yes
	May to Sep. 1980	
Capilano	Aug. 1978 to Oct. 1979	yes
Conuma	Mar. to May 1979	yes
Inches	Mar. to May 1979	yes
Loon	Aug., Sep. 1979; Mar. to Apr. 1980	
	Sep., Nov. 1980	yes
Snootli	Mar. to Jun. 1979	
Proposed/Pilot hatcheries		
Bonaparte	Sep., Nov. 1980	
Hixon	Apr. 1980	
Birkenhead	Jun. 1980	
Chilliwack	Aug. 1978 to Mar. 1980	yes
Nicola	Sep. 1978 to Oct. 1979	yes
Deadman	Nov. 1978 to Aug. 1979	yes
Eagle	Nov. 1979; Sep., Nov. 1980;	
	Mar. to Apr. 1980	yes
Finn	Nov. 1979; Mar., Apr., Sep., Nov., 1980	
Bowron	Nov. 1979	
Cheakamus	Oct. 1980	
Chehalis	May 1980	
Little Qualicum	Nov. 1979	
Lower Puntledge	Jun. 1980	
Nitinat	Jun. 1980	
Quesnel	Apr. 1980	
Raft	Nov. 1979	
Stuart	Apr. 1980	

Table 3. Sampling dates for benthic invertebrates.

Stream	Sampling period		
	Late summer ("max. loading")	Spring ("pre-emergence")	Early summer ("post-cleaning")
Quinsam	30 Aug. 1978	27 Mar. 1979	
	12 Sep. 1979		
Puntledge	29 Aug. 1978	29 Mar. 1979	27 Jun. 1979
Big Qualicum	31 Aug. 1978	26 Mar. 1979	6 Jun. 1979
	27 Sep. 1979		13 Jul. 1979
Capilano	14 Sep. 1979		
Conuma		23 May 1979	
Loon		8 Apr. 1980	
Eagle		9 Apr. 1980	
Finn		9 Apr. 1980	

Table 4. Water chemistry parameters analyzed, analytical methods and detection limits

Parameter	Analytical method	Detection limit
pH	(potentiometric analysis)	0.1
alk.	total alkalinity (potentiometric titration)	0.1 mg·L^{-1} $CaCO_3$
hard.	hardness or bicarbonate alkalinity (sum of Ca & Mg concentrations)	0.1 mg·L^{-1} $CaCO_3$
cond.	conductivity (conductivity cell)	0.1 uS·cm^{-1}
turb.	turbidity (nephelometric analysis)	1.0 FTU
D.O.	dissolved oxygen (Winkler, azide modification)	0.1 mg·L^{-1} O_2
T.R.	total residue (evaporation)	1 mg·L^{-1}
N.F.R.	non-filterable residue (evaporation)	1 mg·L^{-1}
B.O.D.	bio-chemical oxygen demand (5 day incubation at 20°C, oxygen probe	1 mg·L^{-1} O_2
Ca	calcium (inductively coupled argon plasma)	0.05 mg·L^{-1} Ca
Na	sodium (inductively coupled argon plasma)	0.05 mg·L^{-1} Na
Mg	magnesium (inductively coupled argon plasma)	0.10 mg·L^{-1} Mg
K	potassium (atomic emission)	0.01 mg·L^{-1} K
SO_4	sulfate (barium chloranilate, UV spectrophotometric)	1 mg·L^{-1} SO_4
Si	silica (reactive ascorbic acid reduction, colorimetric)	0.5 mg·L^{-1} Si
Cl	chloride (thiocyanate, colorimetric)	0.5 mg·L^{-1} Cl
F	fluoride (fluoride specific ion electrode)	0.05 mg·L^{-1} F
Fe	iron (inductively coupled argon plasma)	0.02 mg·L^{-1} Fe
Cu	copper (inductively coupled argon plasma)	0.01 mg·L^{-1} Cu
Pb	lead (inductively coupled argon plasma)	0.08 mg·L^{-1} Pb
Zn	zinc (inductively coupled argon plasma)	0.02 mg·L^{-1} Zn
Cd	cadmium (inductively coupled argon plasma)	0.01 mg·L^{-1} Cd
Hg	mercury (cold vapour)	0.0002 mg·L^{-1} Hg
TOC	total organic carbon (combustion, infra-red)	1 mg·L^{-1} C
PC	particulate carbon (combustion, thermoconductivity)	0.002 mg·L^{-1} C
PN	particulate nitrogen (combustion, thermoconductivity)	0.02 mg·L^{-1} N
TDN	total dissolved nitrogen (automated UV digestion)	0.005 mg·L^{-1} N
TON	total organic nitrogen (calculated)	0.02 mg·L^{-1} N
t-NO_2	total nitrite (diazotization, colorimetric	0.005 mg·L^{-1} N
t-NO_3	total nitrate (for effluents) (cadmium - copper reduction, colorimetric)	0.01 mg·L^{-1} N
NO_3+NO_2	nitrate plus nitrite (filterable, cadmium - copper reduction, colorimetric)	0.002 mg·L^{-1} N
t-NH_3	total ammonia (for effluents) (phenolhypochlorite colorimetric)	0.005 mg·L^{-1} N
NH_3	ammonia (filterable, indolphenol blue)	0.002 mg·L^{-1} N
t-PO_4 (streams)	total phosphate (ascorbic acid-persulfate digestion, colorimetric)	0.002 mg·L^{-1} P
t-PO_4 (effluent)	total phosphate (acid - persulfate autoclave digestion, colorimetric- molybdate ascorbic acid reduction)	0.005 mg·L^{-1} P

Table 5. Quinsam River, mean chemical concentrations ($\bar{x} \pm s.d.$, n=18 dates[1]).

Parameter ($mg \cdot L^{-1}$)	Mean of sites 1 to 4	Effluent	Cold Creek
pH	7.5 ± 0.2	7.6 ± 0.1	7.8 ± 0.1
alk.	26.78 ± 6.36	40.44 ± 2.94	40.34 ± 4.04
hard.	28.50 ± 6.45	41.78 ± 2.90	42.62 ± 3.97
cond. ($us \cdot cm^{-1}$)	64.2 ± 12.5	91.8 ± 4.0	93.6 ± 5.6
turb. (FTU)	<1.0	<1.0	<1.0
D.O.	11.2 ± 1.3		11.3 ± 0.6
T.R.	53 ± 10	68 ± 4	69 ± 4
N.F.R.	1 ± 3	<1	<1
Ca	8.73 ± 1.80	12.00 ± 0.77	12.12 ± 1.18
Na	1.74 ± 0.34	1.77 ± 0.16	2.10 ± 0.25
Mg	1.63 ± 0.50	2.87 ± 0.29	3.00 ± 0.32
K	0.19 ± 0.05	0.34 ± 0.03	0.39 ± 0.05
SO_4	2.5 ± 0.9	3.1 ± 0.9	2.9 ± 0.5
SiO_4	3.4 ± 0.7	5.3 ± 0.3	5.3 ± 0.2
Cl	1.7 ± 0.5	1.7 ± 0.3	2.0 ± 0.7
F	<0.05	<0.05	<0.05
Fe	0.15 ± 0.04	0.05 ± 0.01	0.07 ± 0.03
Cu	<0.01	<0.01	<0.01
Pb	<0.08	<0.08	<0.08
Zn	<0.02	<0.02	<0.02
Cd	<0.01	<0.01	<0.01
Hg	<0.0002	<0.0002	<0.0002
TOC	2	<1	<1
PC	0.222 ± 0.074	0.182 ± 0.072	0.220 ± 0.065
PN	0.02 ± 0.02	<0.02	<002
TDN	0.155 ± 0.130	0.180 ± 0.125	0.176 ± 0.115
TON	0.09 ± 0.03		0.03 ± 0.02
$t\text{-}NO_2$	<0.005	<0.005	<0.005

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[1] sampled from 30 Aug. 1978 to 24 Oct. 1979

Table 6. Quinsam River, mean nutrient concentrations ($\bar{x}$±s.d.).

Parameter (ug·L^{-1})	Site 1	Site 2	Site 3	Site 4	Cold Creek	Effluent
NO$_3$[1]						
all dates[2]	89 ± 115	100 ± 112	93 ± 106	101 ± 112	123 ± 155	102 ± 96
summer[3]	25 ± 13	48 ± 14	36 ± 12	39 ± 14	69 ± 29	56 ± 11
NH$_3$[1]						
all dates[2]	8 ± 8	19 ± 17	17 ± 11	11 ± 7	4 ± 3	68 ± 26
summer[3]	7 ± 3	31 ± 18	22 ± 11	16 ± 5	6 ± 3	54 ± 13
t-PO$_4$						
all dates[2]	7 ± 2	18 ± 12	16 ± 6	15 ± 4	14 ± 2	37 ± 8
summer[3]	6 ± 2	27 ± 13	17 ± 6	16 ± 4	14 ± 2	35 ± 6
N:P ratio						
summer[3]	5.0:1	2.8:1	3.2:1	3.4:1		

[1] nitrate & ammonia samples from sites 1-4 & Cold Creek were filtered in the field.
[2] all dates (n=18)
[3] summer (May to Oct. 1979, n=8)

Table 7. Quinsam River, mean periphyton biomass concentrations ($\bar{x}$±s.d., n=16 dates[1]).

Parameter	Site 1	Site 2	Site 3	Site 4
			Pools	
Chlorophyll a (mg·m^{-2})	11.5 ±14.0	17.5 ± 20.7	17.3 ± 23.0	9.8 ±13.4
Phaeopigment (mg·m^{-2})	4.3 ± 4.5	10.0 ± 12.0	11.0 ± 21.2	4.8 ± 8.2
Organic weight (g·m^{-2})	6.8 ± 8.1	7.7 ± 11.5	6.3 ± 10.1	4.6 ± 7.4
Number of diatom spp. per sample	34 ± 7	29 ± 9	27 ± 7	29 ± 9
Stream flow over substrate (cm·sec^{-1})	9 ± 9	25 ± 16	16 ± 12	20 ±11
			Riffles	
Chlorophyll a (mg·m^{-2})	1.3 ± 1.9	13.7 ± 24.3	6.6 ± 11.9	3.8 ± 4.4
Phaeopigment (mg·m^{-2})	0.9 ± 1.7	6.6 ± 12.1	5.2 ± 8.5	2.3 ± 3.2
Organic weight (g·m^{-2})	0.7 ± 1.4	3.2 ± 7.0	1.5 ± 2.0	0.9 ± 1.1
Number of diatom spp. per sample	22 ±10	25 ± 8	24 ± 9	25 ± 8
Stream flow over substrates (cm·sec^{-1})	60 ±25	45 ± 15	52 ± 21	56 ±12

[1] sampled from 30 Aug. 1978 to 24 Oct. 1979, duplicate samples

Table 8. Quinsam River, diatom species composition.

Species	Pool sites 1	2	3	4	Riffles sites 1	2	3	4
	(% abundance)[1]				(% abundance)[1]			
Synedra rumpens	12.5	1.2	2.2	3.5	6.3	0.7	0.9	1.2
S. ulna	10.1	1.0	1.5	1.4	5.5	0.6	1.1	0.6
Fragilaria vaucheriae	1.1	0.3	0.6	1.0	0.3	0.1	0.1	0.2
F. capucina var. *mesolepta*	0.3	0.7	0.9	0.6	0.1	1.2	0.1	<0.1
Diatoma tenue	3.8	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Diatoma vulgare	<0.1	2.5	2.2	0.9	<0.1	5.8	0.8	0.3
Achnanthes minutissima	35.9	15.3	34.2	27.4	69.7	19.6	31.8	24.0
A. linearis var. *pusilla*	9.5	1.2	5.7	8.2	3.4	0.7	2.2	2.4
A. affinis	0.3	3.8	1.0	1.4	<0.1	0.7	0.8	0.3
A. lanceolata	0.2	1.0	2.4	2.5	<0.1	1.0	0.8	0.4
Cocconeis placentula	0.3	1.0	1.7	3.3	0.2	0.6	1.1	1.8
Gomphonema angustatum	5.6	0.3	0.6	2.2	5.4	<0.1	0.7	2.7
G. parvulum	1.2	0.6	0.5	1.3	2.2	0.2	0.4	2.4
G. truncatum	3.4	0.5	0.9	1.1	0.5	0.1	0.1	0.2
Cymbella minuta	2.3	6.6	7.7	7.4	0.7	3.0	6.4	4.1
C. minuta var. *silesiaca*	1.7	3.1	2.8	3.3	0.6	4.9	1.6	0.6
C. sinuata	1.0	0.8	5.3	3.5	1.5	3.1	5.8	4.0
Navicula pelliculosa	<0.1	1.5	1.7	5.0	<0.1	30.6	23.8	35.5
Nitzschia palea	2.6	33.2	22.4	12.8	0.5	13.8	13.2	23.3
N. cf. *fonticola*	0.3	17.2	11.0	6.7	0.1	7.0	5.8	4.4
Total diatom # (10^9 cells·m^{-2}·yr^{-1})	2604	7487	3632	2062	789	5101	3473	2569

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[1] percent abundance calculated from annual integration of diatom numbers from 15 sampling dates between 11 Oct. 1978 and 24 Oct. 1979.

Table 9. Quinsam River, mean benthic invertebrate abundance ($\bar{x}\pm$s.d., n=12[1]).

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	12.0±12.6	11.3± 8.8	31.6±28.3	32.5±21.0
Oligochaeta	1.3± 1.0	18.1±14.3	8.0± 9.5	6.8± 7.1
Hydracarina	3.1± 3.2	0.7± 0.6	13.2± 8.7	7.3± 7.2
Copepoda	0.1± 0.1	4.6± 7.2	1.5± 2.6	0.9± 1.1
Ostracoda	1.2± 1.3	1.8± 2.6	1.3± 1.6	1.4± 1.4
Plecoptera, Trichoptera and Ephemeroptera	5.6± 5.7	4.6± 4.1	8.0± 5.3	5.4± 4.0
Total	24.9±23.7	42.6±33.8	67.8±41.7	57.0±38.5

[1] mean of three sampling dates, 4 replicate samples

Table 10. Quinsam River, benthic invertebrate abundance during the three sampling periods (x±s.d., n=4).

A. Maximum loading period (30 Aug. 1978)

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	5.5± 2.7	7.8± 3.1	58.4±34.9	50.8±17.4
Oligochaeta	1.3± 0.6	7.0± 6.7	7.3± 6.6	11.9± 8.4
Hydracarina	1.3± 0.4	0.9± 0.8	9.3± 4.6	8.2± 6.4
Copepoda	0.0	0.1± 0.1	0.2± 0.2	1.2± 0.9
Ostracoda	0.7± 0.5	0.3± 0.2	2.7± 2.1	2.4± 1.6
Plecoptera, Trichoptera and Ephemeroptera	1.3± 0.5	0.8± 0.4	11.3± 7.4	6.4± 5.0
Total	11.9± 5.0	18.2±13.0	91.0±44.0	83.9±43.0

Table 10. Cont'd.

B. Pre-emergence period (27 Mar. 1979)

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	4.8± 1.0	5.3± 3.9	10.4± 5.6	12.6± 7.2
Oligochaeta	0.4± 0.2	12.9± 7.6	0.4± 0.4	1.1± 0.4
Hydracarina	0.8± 0.2	0.2± 0.1	17.0±13.5	0.2± 0.1
Copepoda	0.0	0.0	0.3± 0.3	0.0
Ostracoda	0.1± 0.1	0.0	0.3± 0.3	0.1± 0.1
Plecoptera, Trichoptera and Ephemeroptera	3.3± 1.0	4.0± 1.9	4.9± 2.6	1.8± 1.3
Total	9.6± 2.4	22.9±10.3	33.7±14.1	15.9± 8.7

C. Maximum loading period (12 Sep. 1979)

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	25.3±13.2	20.6± 9.1	25.8±14.0	34.0±10.4
Oligochaeta	2.3± 1.2	34.3± 9.9	16.5±10.7	7.2± 5.3
Hydracarina	7.1± 2.1	0.7± 0.6	13.0± 5.5	13.5± 5.4
Copepoda	0.1±0.1	13.2± 5.3	4.0± 3.1	1.3± 1.0
Ostracoda	2.8± 1.2	5.2± 2.0	0.9± 0.5	1.5± 0.7
Plecoptera, Trichoptera and Ephemeroptera	12.0± 5.4	8.9± 3.8	8.3± 4.2	7.8± 1.7
Total	53.2±20.5	86.7± 2.3	77.9±42.1	71.4± 3.6

Table 11. Puntledge River, mean chemical concentrations ($\bar{x} \pm$ s.d., n=29 dates[1]).

Parameter (mg·L^{-1})	Mean of sites 1 to 4	Effluent
pH	7.3 ± 0.2	7.3 ± 0.2
alk.	17.56 ± 0.62	17.84 ± 0.64
hard.	17.90 ± 1.01	18.32 ± 2.01
cond. (us·cm^{-1})	38.4 ± 1.2	39.3 ± 2.7
turb. (FTU)	<1.0	<1.0
D.O.	11.4 ± 1.1	-
T.R.	31 ± 3	32 ± 3
N.F.R.	<1	<1
Ca	5.67 ± 0.36	5.81 ± 0.72
Na	0.62 ± 0.11	0.61 ± 0.13
Mg	0.91 ± 0.07	0.93 ± 0.07
K	0.05 ± 0.01	0.06 ± 0.01
SO_4	1.0 ± 0.7	1.0 ± 0.9
SiO_4	2.0 ± 0.3	2.0 ± 0.3
Cl	0.4 ± 0.3	0.4 ± 0.3
F	<0.05	<0.05
Fe	0.03 ± 0.03	0.03 ± 0.02
Cu	<0.01	<0.01
Pb	<0.08	<0.08
Zn	<0.02	<0.02
Cd	<0.01	<0.01
Hg	<0.0002	<0.0002
TOC	<1	<1
PC	0.110 ± 0.025	0.261 ± 0.379
PN	<0.02	0.03 ± 0.02
TDN	0.065 ± 0.016	0.113 ± 0.060
TON	0.03 ± 0.01	0.07 ± 0.08
t-NO_2	<0.005	<0.005

[1] sampled from 29 Aug. 1978 to 8 Jul. 1980.

Table 12. Puntledge River, mean nutrient concentrations ($\bar{x} \pm$ s.d.)

Parameter ($\mu g \cdot L^{-1}$)	Site 1	Site 2	Site 3	Site 4	Effluent
NO_3[1]					
all dates[2]	39 ± 14	38 ± 14	38 ± 14	38 ± 14	41 ± 13
spring[3]	47 ± 6	46 ± 7	46 ± 7	45 ± 8	41 ± 10
NH_3[1]					
all dates[2]	4 ± 3	8 ± 5	6 ± 5	5 ± 4	17 ± 16
spring[3]	3 ± 3	6 ± 3	5 ± 2	4 ± 2	17 ± 19
t-PO_4					
all dates[2]	<2	4 ± 2	3 ± 2	3 ± 2	10 ± 10
spring[3]	<2	4 ± 2	3 ± 2	3 ± 2	13 ± 11
N:P ratio					
annual[4]	>17:1	12:1	17:1	17:1	
spring[3]	>23:1	14:1	16:1	18:1	

[1] nitrate & ammonia samples from sites 1 to 4 were filtered in the field.
[2] all dates (n=29)
[3] spring (Mar. to Jun. 1979 and 1980, n=11)
[4] annual (Aug. 1978 to Jul. 1979, n=15)

Table 13. Puntledge River, mean periphyton biomass accumulations ($\bar{x} \pm$ s.d., n=28 dates[1])

Parameter	Site 1	Site 2	Site 3	Site 4
	Pools			
Chlorophyll a ($mg \cdot m^{-2}$)	0.6 ± 0.7	56.4 ±110.7	12.8 ± 27.2	3.0 ± 3.4
Phaeopigment ($mg \cdot m^{-2}$)	0.8 ± 1.4	63.7 ±118.7	11.3 ± 20.6	3.7 ± 5.8
Organic weight ($g \cdot m^{-2}$)	0.7 ± 0.8	14.8 ± 17.7	3.3 ± 4.0	1.0 ± 1.2
Number of diatom spp. per sample	38 ±14	37 ± 8	34 ± 8	31 ± 9
Stream flow over substrates ($cm \cdot sec^{-1}$)	11 ± 8	8 ± 7	17 ± 11	13 ± 9
	Riffles			
Chlorophyll a ($mg \cdot m^{-2}$)	0.2 ± 0.3	14.1 ± 35.1	2.0 ± 3.3	1.4 ± 2.1
Phaeopigment ($mg \cdot m^{-2}$)	0.3 ± 0.6	12.0 ± 21.6	3.1 ± 6.2	1.8 ± 3.3
Organic weight ($g \cdot m^{-2}$)	0.2 ± 0.2	3.0 ± 4.8	1.1 ± 1.9	0.8 ± 1.2
Number of diatom spp. per sample	29 ±11	26 ± 8	24 ± 9	24 ± 9
Stream flow over substrates ($cm \cdot sec^{-1}$)	34 ±13	45 ± 17	52 ± 20	41 ±18

[1] sampled from 29 Aug. 1978 to 8 Jul. 1980, duplicate samples

Table 14a. Puntledge River, diatom species composition, 1978 - 1979.

Species	Pool sites 1[1]	 2	(% abundance[2]) 3	 4	Riffles sites 1	 2	(% abundance[2]) 3	 4
Synedra rumpens		2.8	8.5	13.3	12.7	5.2	3.7	11.8
S. ulna		1.3	5.0	4.6	4.0	8.0	6.6	6.4
S. delicatissima		0.8	0.9	0.5	7.9	0.9	1.0	2.2
Tabellaria fenestrata		1.4	1.9	1.7	38.2	1.7	0.4	0.4
Fragilaria vaucheriae		0.2	0.9	0.6	0.4	0.6	0.2	0.2
F. crotonensis		5.4	1.6	0.9	<0.1	1.5	0.1	0.4
F. capucina var. *mesolepta*		10.3	3.9	0.5	0.1	2.3	0.1	<0.1
Diatoma tenue		<0.1	0.6	0.8	1.4	0.6	0.2	1.3
D. hiemale var. *mesodon*		0.1	<0.1	0.2	<0.1	0.2	<0.1	<0.1
Hannaea arcus		0.6	4.8	3.6	0.4	11.4	39.2	8.9
Achnanthes minutissima		19.7	49.4	56.8	33.1	45.1	37.7	59.1
A. linearis var. *pusilla*		6.2	2.2	1.3	0.4	2.4	0.5	0.7
Gomphonema angustatum		0.4	1.2	1.5	0.2	7.7	6.6	3.0
G. parvulum		0.3	0.8	0.8	0.1	2.1	2.7	1.3
G. Suclavatum		0.3	1.2	1.5	0.1	1.3	1.2	1.5
Cymbella minuta		3.1	2.9	2.6	0.2	0.7	0.3	0.6
C. minuta var. *silesiaca*		1.6	2.2	1.9	0.1	0.7	0.1	0.2
Anomoeneis vitrea		0.5	0.7	0.5	0.4	0.3	0.2	0.2
Nitzschia sp.		5.4	2.0	1.1	0.1	3.0	0.2	0.1
N. kuetzingiana		2.6	0.7	0.3	0.1	3.9	0.1	<0.1
N. palea		15.7	2.5	1.0	0.2	1.9	0.3	0.2
N. cf. *fonticola*		15.8	1.4	0.6	0.1	0.9	0.1	0.2
Total diatom number (10^9 cells·m^{-2}·yr^{-1})		19898	2542	762	329	4748	776	1337

[1] insufficient data for site 1 pools

[2] percent abundance calculated from annual integration of diatom numbers from 15 sampling dates between 29 Aug. 1978 and 6 Sep. 1979

Table 14b. Puntledge River, diatom species composition, 1979-1980.

Species	Pool sites				Riffle sites			
	1	2	3	4	1	2	3	4
	(% abundance[1])				(% abundance[1])			
Synedra rumpens	11.4	10.2	7.4	7.1	8.5	3.8	4.4	6.9
S. ulna	4.5	5.0	4.3	3.5	3.3	3.6	3.2	3.3
S. delicatissima	6.6	1.4	0.6	0.5	5.6	0.8	0.5	0.7
Tabellaria fenestrata	50.2	3.3	1.5	0.6	39.7	0.6	0.2	0.3
F. vaucheriae	0.3	1.9	2.0	2.0	0.3	0.9	1.4	0.6
F. crotonensis	0.4	3.9	2.1	0.9	0.3	1.2	0.9	0.5
F. capucina var. *mesolepta*	0.0	0.8	0.9	0.3	0.0	0.1	<0.1	<0.1
Diatoma tenue	1.1	0.3	0.3	0.3	0.9	0.5	0.2	0.6
D. hiemale var. *mesodon*	<0.1	1.4	1.1	0.4	<0.1	3.9	0.5	0.2
Hannaea arcus	0.3	4.9	11.3	3.5	0.2	17.4	30.8	10.4
Achnanthes minutissima	9.1	37.9	52.4	71.9	14.7	50.2	49.1	68.0
A. linearis var. *pusilla*	0.5	5.7	4.0	2.2	0.1	3.6	1.2	1.9
Gomphonema angustatum	0.1	1.1	0.7	2.2	0.1	8.3	2.7	3.9
G. parvulum	0.1	1.6	1.3	1.2	0.1	1.5	3.0	1.3
G. subclavatum	0.3	0.8	1.3	0.8	0.1	0.6	1.3	0.7
Cymbella minuta	0.6	0.9	2.1	0.9	0.1	0.5	0.5	0.3
C. minuta var. *silesiaca*	0.1	0.6	0.5	0.3	0.1	0.2	0.1	0.1
Anomoeneis vitrea	1.3	0.7	0.5	0.2	0.5	0.1	<0.1	0.1
Nitzschia sp.	0.2	0.8	1.3	0.4	0.1	0.1	0.1	<0.1
N. kuetzingiana	0.1	3.5	0.9	0.1	<0.1	1.7	<0.1	<0.1
N. palea	0.3	5.6	2.3	0.3	0.1	0.3	0.1	<0.1
N. cf. *fonticola*	0.2	3.0	1.1	0.2	0.1	0.1	0.1	<0.1
Total diatom number (10^9 cells·m^{-2}·yr^{-1})	604	3668	4375	2594	344	4147	2146	2661

[1] percent abundance calculated from annual integration of diatom numbers from 16 sampling dates between 4 Jul. 1979 and 8 Jul. 1980.

Table 15. Puntledge River, mean benthic invertebrate abundance ($\bar{x}$±s.d., n=12[1])

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	3.2± 2.1	32.3±25.6	17.9±12.7	4.2± 4.6
Oligochaeta	1.0± 0.9	3.3± 3.2	1.3± 1.0	1.1± 1.6
Hydracarina	0.3± 0.3	2.6± 2.0	5.3± 4.8	2.7± 3.6
Copepoda	1.0± 0.8	2.4± 2.2	0.4± 0.4	0.3± 0.4
Ostracoda	0 ± 0	0.1± 0.4	1.8± 3.0	1.5± 2.2
Plecoptera, Trichoptera and Ephemeroptera	2.9± 1.3	18.7± 7.5	16.2±12.6	10.3±13.1
Total	9.1± 2.9	62.6±35.2	45.0±20.7	20.6±22.9

[1] mean of 3 sampling dates, 4 replicate samples

Table 16. Puntledge River, benthic invertebrate abundance during the three sampling periods ($\bar{x}$±s.d., n=4).

A. Maximum loading period (29 Aug. 1978)

Date	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	1.6± 1.1	27.9±17.1	19.7± 8.4	1.1± 1.0
Oligochaeta	1.1± 0.5	4.8± 3.0	0.8± 0.5	0.3± 0.2
Hydracarina	0.6± 0.1	4.0± 2.8	3.5± 1.6	1.2± 0.9
Copepoda	1.1± 0.8	1.4± 1.2	0.0	0.0
Ostracoda	0.0	0.0	0.2± 0.2	0.3± 0.2
Plecoptera, Trichoptera and Ephemeroptera	4.0± 1.6	15.0± 5.1	3.7± 2.1	0.8± 0.8
Total	9.1± 2.1	55.1±30.7	29.2±12.0	4.1± 3.7

B. Pre-emergence period (29 Mar. 1979)

Date	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	5.8± 0.8	59.7±21.1	28.9±13.0	6.1± 6.1
Oligochaeta	1.7± 1.0	2.3± 2.3	2.1± 1.4	1.8± 2.3
Hydracarina	0.2± 0.1	2.6± 1.8	1.2± 0.2	0.7± 0.7
Copepoda	1.7± 0.5	1.9± 1.4	0.6± 0.5	0.3± 0.3
Ostracoda	0.0	0.3± 0.2	1.4± 0.5	1.9± 1.9
Plecoptera, Trichoptera and Ephemeroptera	2.0± 1.0	24.1± 5.7	31.5± 6.0	20.1±13.6
Total	12.0± 1.3	95.4±33.4	66.6±20.7	31.7±33.0

C. Post-cleaning period (27 Jun. 1979)

Date	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	2.2± 0.8	10.0± 3.0	5.5± 1.9	5.1± 3.9
Oligochaeta	0.1± 0.1	2.8± 2.6	1.0± 0.7	1.2± 1.1
Hydracarina	0.1± 0.1	1.5± 1.0	11.0± 3.8	6.0± 4.9
Copepoda	0.3± 0.3	3.5± 3.4	0.1± 0.1	0.5± 0.5
Ostracoda	0.0	0.0	3.8± 3.5	2.4± 2.4
Plecoptera, Trichoptera and Ephemeroptera	2.7± 0.7	15.7± 9.5	11.6± 1.6	10.4± 7.1
Total	6.2± 1.4	37.1±15.3	39.2± 5.1	26.1±18.9

Table 17. Big Qualicum River, mean chemical concentrations (x±s.d., n=16 dates[1])

Parameter (mg·L^{-1})	Mean of sites 1 to 6	Effluent (mean of the 4 discharges)
pH	7.6 ± 0.1	7.6 ± 0.1
alk.	35.46 ± 5.08	36.28 ± 2.81
hard.	37.22 ± 2.85	36.92 ± 3.42
cond. (us·cm^{-1})	78.8 ± 5.0	80.5 ± 4.9
turb. (FTU)	1.5 ± 6.7	3.1 ± 10.4
D.O.	11.2 ± 0.8	
T.R.	58 ± 17	61 ± 19
N.F.R.	3 ± 13	5 ± 19
Ca	12.06 ± 0.87	11.85 ± 0.99
Na	1.32 ± 0.27	1.37 ± 0.21
Mg	1.72 ± 0.25	1.78 ± 0.35
K	0.15 ± 0.03	0.18 ± 0.03
SO_4	2.2 ± 0.4	2.2 ± 0.4
SiO_4	3.1 ± 0.5	3.3 ± 0.3
Cl	1.4 ± 0.2	1.4 ± 0.2
F	<0.05	<0.05
Fe	0.08 ± 0.18	0.14 ± 0.16
Cu	<0.01	<0.01
Pb	<0.08	<0.08
Zn	<0.02	<0.02
Cd	<0.01	<0.01
Hg	<0.0002	<0.0002
TOC	1 ± 1	1 ± 1
PC	0.349 ± 1.060	0.268 ± 0.125
t-NO_2	<0.005	<0.005

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[1] sampled between 31 Aug. 1978 and 4 Oct. 1979, and between 27 May and 10 Sep. 1980

Table 18. Big Qualicum River, mean nutrient concentrations ($\bar{x}$±s.d.).

Parameter ug·L^{-1}	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Effluent (experimental channel)	Effluent (main hatchery)
NO_3[1]								
- all dates[2]	46±19	59±49	52±21	59±23	60±23	62±23	56±16	62±22
- summer 79[3]	37± 6	40± 6	39± 8	48±12	50±13	52±13	47± 9	50± 9
- summer 80[4]	63± 9	64± 9	66±12	66± 8	68± 9	70± 9		
NH_3[1]								
- all dates[2]	7± 3	11±11	12±13	31±29	30±29	29±28	15±10	58±29
- summer 79[3]	9± 2	12± 4	10± 7	38±22	36±15	33±14	20± 9	54±31
- summer 80[4]	6± 2	8± 5	8± 4	19±11	18± 8	16± 5		
PO_4								
- all dates[2]	8± 2	9± 3	12± 4	17± 5	19± 6	18± 5	11± 4	29±10
- summer 79[3]	10± 2	12± 2	15± 2	21± 4	21± 4	21± 3	14± 3	26±10
- summer 80[4]	8± 2	8± 2	11± 2	17± 5	17± 4	17± 2		
N:P ratio								
- summer 79	4.5:1	4.3:1	3.4:1	3.6:1	3.8:1	3.8:1		
- summer 80	8.3:1	8.4:1	6.8:1	5.3:1	5.1:1	5.2:1		

[1] nitrate and ammonia samples from sites 1 to 6 were filtered in the field
[2] all dates (n=25)
[3] summer 1979 (May - Sep., n=6)
[4] summer 1980 (May - Sep., n=9)

Table 19. Big Qualicum River, mean periphyton biomass accumulation ($\bar{x}$±s.d., n=15 dates[1]).

Parameter		Riffles	
	Site 1	Site 2	Site 3
Chlorophyll a (mg·m^{-2})	5.3 ±12.8	25.8 ± 73.8	22.6 ± 67.4
Phaeopigment (mg·m^{-2})	5.1 ± 9.7	18.0 ± 44.4	13.7 ± 40.4
Organic weight (g·m^{-2})	1.0 ± 1.7	5.3 ± 11.8	4.9 ± 10.7
Number of diatom spp. per sample	24 ± 9	28 ± 6	26 ± 8
Stream flow over substrates (cm·sec^{-1})	60 ±21	58 ± 27	61 ± 29
		Riffles	
	Site 4[2]	Site 5[2]	Site 6[2]
Chlorophyll a (mg·m^{-2})	19.2 ±54.1	13.6 ± 30.2	25.7 ± 63.8
Phaeopigment (mg·m^{-2})	11.1 ±32.3	10.3 ± 20.8	15.2 ± 38.0
Organic weight (g·m^{-2})	3.9 ±10.5	2.8 ± 5.3	5.0 ± 11.8
Number of diatom spp. per sample	28 ± 7	27 ± 7	26 ± 7
Stream flow over substrates (cm·sec^{-1})	50 ±24	47 ± 15	54 ± 20

[1] sampled between 2 Sep. 1978 and 11 Sep. 1979, duplicate samples

[2] values approximate: many summer samples lost because of coverage by drifted Cladophora

Table 20. Big Qualicum River, diatom species composition.

Species	Riffle Sites					
	1	2	3	4[1]	5[1]	6[1]
	(% abundance[2])					
Synedra rumpens	1.6	1.7	1.0	1.9	1.7	1.5
S. ulna	1.8	3.3	4.8	3.6	4.8	7.7
Fragilaria vaucheriae	<0.1	0.5	0.9	0.2	0.5	0.2
F. construens	<0.1	4.2	2.2	2.0	1.0	0.9
Hannaea arcus	9.3	11.6	10.9	4.5	7.6	8.6
Diatoma hiemale var. *mesodon*	<0.1	0.2	0.1	0.2	<0.1	<0.1
D. vulgare	0.1	20.0	24.0	2.5	5.9	8.2
Cocconeis placentula	0.5	1.3	3.7	3.3	4.9	2.9
Achnanthes minutissima	18.0	10.0	11.3	16.3	16.9	9.7
A. lanceolata	0.1	0.6	1.0	0.4	0.6	0.4
A. linearis var. *pusilla*	0.1	0.4	0.4	0.6	0.2	0.3
Gomphonema angustatum	1.7	1.3	1.8	0.6	1.3	0.6
G. parvulum	4.5	2.4	3.0	0.6	1.2	2.1
Cymbella minuta	0.1	0.3	1.3	10.8	10.9	6.0
C. minuta var. *silesiaca*	0.3	1.3	2.9	6.1	8.9	4.4
C. sinuata	0.8	0.8	2.0	0.9	1.8	1.4
Navicula pelliculosa	50.7	26.1	16.6	23.7	22.5	35.5
Nitzschia cf. *fonticola*	0.6	0.8	2.1	2.5	3.6	1.3
N. palea	7.3	4.6	3.7	8.7	6.5	6.7
N. acicularis	0.3	3.9	1.4	2.6	<0.1	0.3
Total diatom number (10^9 cells·m^{-2}·yr^{-1})	4460	3290	2008	3384	1837	3560

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[1] values approximate: many summer samples lost because of coverage by drifted *Cladophora*

[2] percent abundance calculated from annual integration of diatom numbers from 15 sampling dates between 20 Sep. 1978 and 11 Sep. 1979

Table 21. Big Qualicum River, benthic invertebrate abundance during the five sampling periods ($\bar{x}$±s.d., n=4).

A. Maximum loading period (31 Aug. 1978)

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 4	Site 6
Diptera	41.1±14.6	56.0±25.1	65.3±37.6	139.2±42.6
Oligochaeta	2.5± 1.3	4.4± 4.1	10.4± 4.4	23.8±14.4
Hydracarina	1.7± 0.9	4.8± 2.5	3.9± 2.1	12.1± 5.4
Copepoda	5.1± 3.4	18.1± 5.9	20.4±15.4	30.1±12.1
Ostracoda	6.3± 1.8	21.9±14.8	1.4± 0.5	2.6± 2.9
Plecoptera, Trichoptera and Ephemeroptera	20.1± 5.4	16.5± 6.4	14.4±11.5	11.1± 4.4
TOTAL	77.5±17.9	131.7±54.8	121.4±65.6	226.2±74.4

B. Pre-emergence period (26 Mar. 1979)

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 4	Site 6
Diptera	4.1± 2.9	12.0± 5.4	62.7±40.3	8.7± 1.8
Oligochaeta	0.1± 0.1	0.1± 0.1	0.7± 0.6	0.2± 0.2
Hydracarina	0.4± 0.2	2.1± 1.4	2.3± 1.4	0.9± 0.4
Copepoda	0.3± 0.3	1.5± 0.9	2.7± 3.0	0.7± 0.3
Ostracoda	0.6± 0.5	2.4± 1.0	0.9± 1.2	0.4± 0.2
Plecoptera, Trichoptera and Ephemeroptera	8.1± 5.6	12.6± 2.1	6.9± 5.3	5.7± 2.5
TOTAL	13.8± 9.7	31.4± 9.9	76.6±51.2	16.7± 5.1

C. Post-cleaning period (6 Jun. 1979)

Order	Abundance (10^3 organisms·m^{-2}) Site 3	Site 3a	Site 4	Site 6
Diptera	5.1± 2.6	14.8± 9.4	26.1±14.5	17.0±11.7
Oligochaeta	0.2± 0.2	1.3± 0.9	16.2±14.2	5.5± 6.4
Hydracarina	5.0± 2.7	7.7± 4.2	4.1± 2.6	2.5± 1.3
Copepoda	0.7± 0.7	5.2± 2.9	2.8± 3.0	3.7± 2.1
Ostracoda	1.5± 0.6	6.4± 4.4	1.5± 0.4	2.3± 1.7
Plecoptera, Trichoptera and Ephemeroptera	5.6± 4.4	11.0± 3.4	5.7± 3.8	2.4± 1.4
TOTAL	18.8±10.3	47.9±23.2	58.2±36.5	34.0±21.6

D. Post-cleaning period (13 Jul. 1979)

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 2a	Site 3
Diptera	26.7± 6.8	11.4± 3.1	27.9± 6.0	22.9± 7.0
Oligochaeta	1.4± 1.2	2.2± 0.8	2.1± 1.5	0.8± 0.3
Hydracarina	4.0± 2.2	4.1± 1.3	3.3± 0.9	4.6± 1.3
Copepoda	1.3± 0.9	1.2± 0.5	0.4± 0.6	0.9± 0.4
Ostracoda	2.1± 1.4	7.5± 2.5	1.7± 1.7	2.6± 1.4
Plecoptera, Trichoptera and Ephemeroptera	16.5± 1.7	7.7± 0.7	13.7± 3.0	11.5± 1.6
TOTAL	53.5± 9.1	36.8± 5.7	49.7± 8.2	45.2± 6.5

E. Maximum loading period (27 Sep. 1979)

Order	Abundance (10^3 organisms·m^{-2}) Site 3a	Site 4	Site 5	Site 6
Diptera	25.8±11.9	59.2±14.9	32.4±19.1	60.0± 2.8
Oligochaeta	1.3± 0.5	13.3± 5.3	12.0± 4.6	5.9± 1.5
Hydracarina	3.5± 1.2	2.3± 1.4	0.7± 0.8	2.2± 1.3
Copepoda	11.6± 2.1	9.5± 6.7	1.7± 1.4	10.2± 3.7
Ostracoda	0.9± 0.8	1.1± 0.9	1.2± 0.7	1.2± 1.2
Plecoptera, Trichoptera and Ephemeroptera	14.4± 9.9	12.7± 7.4	2.0± 1.9	4.5± 2.4
TOTAL	62.4±27.4	109.1±26.8	54.2±28.1	99.0± 4.0

Table 22. Capilano River, mean chemical concentrations ($\bar{x} \pm$ s.d., n=19 dates[1]).

Parameter ($\mathrm{mg \cdot L^{-1}}$)	Mean of sites 1 to 4	Effluent	Holgate Creek tributary
pH	6.6 ± 0.1	6.6 ± 0.1	7.3 ± 0.2
alk.	5.34 ± 1.22	5.42 ± 0.79	21.91 ± 0.53
hard.	6.00 ± 1.63	5.95 ± 0.91	30.19 ± 0.41
cond. (us·cm^{-2})	17.9 ± 6.6	18.0 ± 2.3	112.7 ± 46.3
turb. (FTU)	<1.0	<1.0	1.7 ± 2.3
D.O.	11.6 ± 1.2	10.3 ± 1.3	11.0 ± 1.2
T.R.	21 ± 5	22 ± 5	90 ± 44
N.F.R.	<1	<1	15 ± 49
Ca	1.95 ± 0.53	1.90 ± 0.28	10.70 ± 3.76
Na	0.69 ± 0.56	0.62 ± 0.68	8.46 ± 6.53
Mg	0.27 ± 0.08	0.29 ± 0.06	0.84 ± 0.30
K	0.22 ± 0.09	0.24 ± 0.03	0.80 ± 0.24
SO_4	2.0 ± 0.5	2.1 ± 0.7	5.5 ± 0.8
SiO_4	1.8 ± 0.4	1.9 ± 0.3	3.2 ± 0.7
Cl	<0.5	0.6 ± 0.3	15.5 ± 12.5
F	<0.05	<0.05	<0.05
Fe	0.13 ± 0.07	0.63 ± 1.60	0.12 ± 0.05
Cu	<0.01	<0.01	<0.01
Pb	<0.08	<0.08	<0.08
Zn	<0.02	<0.02	<0.02
Cd	<0.01	<0.01	<0.01
Hg	<0.0002	<0.0002	<0.0002
TOC	1 ± 1	1 ± 1	5 ± 10
PC	0.196 ± 0.153		0.771 ± 1.663
PN	0.02		0.03 ± 0.05
TDN	0.195 ± 0.072		0.540 ± 0.183
TON	0.02 ± 0.02		0.10 ± 0.11
t-NO_2	<0.005	<0.005	<0.005

[1] sampled between 6 Sep. 1978 and 11 Oct. 1979

Table 23. Capilano River, mean nutrient concentrations ($\bar{x}$±s.d.).

Parameter (ug·L^{-1})	Site 1	Site 2	Site 3	Site 4	Holgate Creek	Effluent
NO$_3$[1]						
all dates[2]	153 ± 52	154 ± 53	160 ± 51	198 ± 83	453 ± 158	157 ± 55
summer[3]	115 ± 29	116 ± 30	124 ± 28	144 ± 41	337 ± 83	125 ± 27
NH$_3$[1]						
all dates[2]	8 ± 4	17 ± 12	19 ± 14	9 ± 7	12 ± 14	58 ± 26
summer[3]	6 ± 4	15 ± 12	16 ± 12	5 ± 4	21 ± 19	57 ± 20
PO$_4$						
all dates[2]	2 ± 2	9 ± 6	8 ± 6	6 ± 6	38 ± 92	19 ± 10
summer[3]	<2	9 ± 6	8 ± 6	4 ± 3	29 ± 30	19 ± 10
N:P ratio						
summer[3]	>45:1	23:1	28:1	38:1		

[1] nitrate & ammonia samples from sites 1-4 & Holgate Creek filtered in the field
[2] all dates (n=19)
[3] summer (May to Oct., n=8)

Table 24. Capilano River, mean periphyton biomass accumulations ($\bar{x}$±s.d., n=16 dates[1]).

Parameter	Site 1	Site 2	Site 3[2]	Site 4
		Pools		
Chlorophyll a (mg·m^{-2})	0.7 ± 0.8	14.4 ± 15.6	6.1 ± 8.7	10.1 ± 9.3
Phaeopigment (mg·m^{-2})	1.1 ± 2.0	6.1 ± 6.6	3.9 ± 5.8	3.3 ± 3.5
Organic weight (g·m^{-2})	0.7 ± 0.7	7.2 ± 6.1	2.0 ± 3.6	2.9 ± 3.0
Number of diatom spp per sample	35 ± 8	26 ± 7	27 ± 8	22 ± 6
Stream flow over substrates (cm·sec^{-1})	3 ± 8	4 ± 7	6 ± 5	9 ± 6
		Riffles		
Chlorophyll a (mg·m^{-2})	0.1 ± 0.1	7.7 ± 10.1		3.2 ± 8.2
Phaeopigment (mg·m^{-2})	0.1 ± 0.1	4.1 ± 5.3		2.7 ± 7.4
Organic weight (g·m^{-2})	0.1 ± 0.2	2.0 ± 3.5		0.9 ± 2.2
Number of diatom spp per sample	35 ± 8	24 ± 6		22 ± 9
Stream flow over substrates (cm·sec^{-1})	16 ±21	20 ± 14		45 ±23

[1] sampled between 30 Oct. 1978 and 11 Oct. 1979, duplicate samples
[2] few data for site 3 riffles; flooding and vandalism often eliminated samples

Table 25. Capilano River, diatom species composition.

Species	Pool sites				Riffle sites			
	1	2	3	4	1	2	3[1]	4
	(% abundance[2])				(% abundance[2])			
Synedra rumpens	12.4	11.4	12.6	16.6	17.0	17.6		8.3
Tabellaria flocculosa	11.1	0.9	2.3	1.7	10.3	1.1		0.6
Diatoma hiemale var. *mesodon*	0.4	6.2	1.6	2.2	0.8	4.1		0.1
Hannaea arcus	2.2	1.3	5.1	5.2	3.8	1.0		1.7
Fragilaria vaucheriae	0.3	1.4	0.6	2.7	1.5	0.7		0.4
Eunotia pectinalis var. *minor*	3.0	0.2	0.6	0.3	3.2	0.3		<0.1
Achnanthes minutissima	30.4	29.8	30.9	39.4	28.5	15.6		44.6
A. gibberula	8.0	1.5	1.7	1.8	7.0	1.3		0.6
A. affinis	0.7	5.7	2.0	<0.1	2.0	1.7		<0.1
Gomphonema angustatum	0.8	7.9	14.7	6.8	1.0	16.1		2.7
Cymbella minuta	4.4	22.3	12.0	9.4	1.5	18.7		0.7
Nitzschia sp. (faint)	0.2	7.3	12.1	4.0	0.3	5.1		0.5
N. palea	0.5	4.0	3.5	0.3	0.9	4.2		<0.1
Total diatom number (10^9 cells·m^{-2}·yr^{-1})	250	3051	1309	1644	62	699		957

[1] few data for site 3 riffles; flooding and vandalism often eliminated samples.

[2] percent abundance calculated from annual integration of diatom numbers from 13 sampling dates between 3 Oct 1978 and 11 Oct 1979.

Table 26. Capilano River, benthic invertebrate abundance ($\bar{x}$±s.d., n=4).
Maximum loading period 14 Sept 1979.

Order	Abundance (10^3 organisms·m^{-2})			
	Site 1	Site 2	Site 3	Site 4
Diptera	2.6± 2.7	20.1±17.7	39.4±38.6	97.4±42.3
Oligochaeta	0.1± 0.1	1.5± 2.3	3.2± 3.5	2.3± 2.0
Hydracarina	0.2± 0.1	2.3± 1.2	4.9± 4.9	10.9± 4.7
Copepoda	0.1± 0.1	0.1± 0.1	1.8± 2.0	0 ± 0
Ostracoda	0 ± 0	0 ± 0	2.1± 2.5	0.1± 0.3
Plecoptera, Trichoptera and Ephemeroptera	0.4± 0.4	2.9± 3.3	15.6±14.7	4.8± 2.6
Total	3.7± 2.5	29.7±28.1	67.2±60.0	115.4±49.5

Table 27. Chemical composition of streams with seasonal (spring) hatchery operations ($\bar{X}$±s.d.).

Parameter ($mg \cdot L^{-1}$)	Conuma River	Leagh Creek	Inches Creek	Barnes Creek	Loon Creek	Loon Creek tributary	Hixon Creek	Snootli Creek tributary
pH	7.0 ± 0.3	7.1 ± 0.3	6.5 ± 0.2	6.5 ± 0.1	8.4 ± 0.1	8.2 ± 0.1	6.0 ± 0.1	6.9 ± 0.2
alk.	8.67 ± 2.11	9.14 ± 1.92	10.1 ± 0.8	10.9 ± 0.9	211 ± 22	250 ± 2	2.48 ± 0.11	8.04 ± 0.6
hard.	8.67 ± 1.99	9.20 ± 2.00	11.1 ± 0.7	13.5 ± 0.7	181 ± 10	212 ± 4	3.56 ± 0.72	11.7 ± 0.8
cond. ($us \cdot cm^{-1}$)	21 ± 5	23 ± 5	32 ± 3	39 ± 2	462 ± 32	496 ±10	11 ± 2	33 ± 2
turb. (FTU)	<1	<1	<1	<1	<1	<1	<1	<1
D.O.	12.6 ± 0.4		11.0 ± 1.1	11.4 ± 0.2	10.9 ± 0.7	10.0 ± 0.7		
T.R.	19 ± 4	21 ± 3	30 ± 3	33 ± 3	270 ± 26	312 ± 6	18 ± 1	28 ± 2
N.F.R.	<1	<1	<1	<1	3 ± 5	<1	<1	<1
Ca	3.00 ± 0.71	3.23 ± 0.71	3.73 ± 0.21	4.50 ± 0.25	26.0 ± 2.0	35.6 ± 1.6	1.26 ± 0.25	4.35 ± 0.29
Na	0.52 ± 0.14	0.58 ± 0.13	1.17 ± 0.07	1.00 ± 0.05	24.6 ± 3.5	26.2 ± 1.4	0.46 ± 0.05	0.54 ± 0.10
Mg	0.28 ± 0.05	0.26 ± 0.06	0.44 ± 0.04	0.54 ± 0.03	28.2 ± 2.4	30.0 ± 0.6	0.104 ± 0.023	0.20 ± 0.01
K	0.03 ± 0.01	0.07 ± 0.01	0.29 ± 0.04	0.53 ± 0.04	5.49 ± 0.56	6.02 ± 0.17	0.17 ± 0.04	0.66 ± 0.02
SO_4	1.4 ± 0.3	1.5 ± 0.3	2.1 ± 0.3	2.2 ± 0.2	12.6 ± 4.3	17.9 ± 2.2		6.0 ± 0.4
SiO_2	1.0 ± 0.3	0.7 ± 0.7	3.1 ± 0.2	3.2 ± 0.1	9.7 ± 1.9	13.3 ± 2.2	<0.5	2.6 ± 0.3
Cl	0.6 ± 0.4	0.6 ± 0.5	0.8 ± 0.1	1.4 ± 0.1	2.3 ± 0.4	2.5 ± 0.4	<0.5	<0.5
F	<0.05	<0.05	<0.05	<0.05	0.20 ± 0.02	0.20 ± 0.02	<0.05	<0.05
Fe	0.03 ± 0.04	<0.02	0.07 ± 0.07	0.02 ± 0.02	0.08 ± 0.06	0.03 ± 0.04	<0.02	<0.02
Cu	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Zn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
TOC	1 ± 1	2 ± 1	1 ± 1	1 ± 1				<1
PC	0.048 ± 0.033	0.014	0.266 ± 0.168	0.177 ± 0.05	0.413 ± 0.197	0.225 ± 0.213	0.140 ± 0.114	0.036 ± 0.043
PN	<0.02	<0.02	0.03 ± 0.02	0.03 ± 0.02	0.04 ± 0.02	0.02 ± 0.04	0.02 ± 0.02	0.02 ± 0.05
TDN	0.046 ± 0.012	0.053	0.497 ± 0.161	0.974 ± 0.59	0.380 ± .042	0.425 ± 0.184	0.116 ± 0.044	0.221 ± 0.017
TON	0.02 ± 0.01	0.03	0.07 ± 0.08	0.28 ± 0.46	0.24 ± 0.11	0.13 ± 0.13	0.04 ± 0.03	0.02 ± 0.03
$t\text{-}NO_2$	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
No. sites	4	1	4	4	4	2	4	2
No. dates	4	4	4	4	5	5	1	8

Table 28. Nutrient concentrations in streams with seasonal hatchery operations ($\bar{x}$±s.d.[1]).

Watercourse	Site	NO_3 (ug·L^{-1})	NH_3 (ug·L^{-1})	PO_4 (ug·L^{-1})	N:P
Conuma River	1	28 ± 9	<2	<2	>12:1
	2	27 ± 7	2 ± 2	<2	>11:1
	3	26 ± 7	2 ± 2	<2	>11:1
	4	25 ± 6	2 ± 2	<2	>11:1
	Leagh Cr.	23	<2	<2	>11:1
	effluent	68 ± 23	<5	<5	
Inches Creek	Barnes Cr.	691 ± 128	20 ± 11	11 ± 2	63 :1
	1	345 ± 50	15 ± 11	11 ± 4	36 :1
	2	420 ± 88	33 ± 9	33 ± 9	15 :1
	3	391 ± 91	40 ± 18	40 ± 30	17 :1
	4	454 ± 104	31 ± 20	28 ± 9	20 :1
Loon Creek	1	153 ± 86	6 ± 4	99 ± 15	1.6:1
	2	162 ± 76	24 ± 20	115 ± 34	1.9:1
	3	167 ± 80	21 ± 15	101 ± 13	1.8:1
	4	165 ± 79	19 ± 12	104 ± 13	1.7:1
	tributary	256 ± 12	3 ± 3	71 ± 3	3.7:1
	effluent	245 ± 16	103 ± 78	129 ± 34	
Hixon Creek	1	59	2	2	30 :1
	2	60	3	4	16 :1
	influent	98	6	14	7.4:1
	effluent	79	66	30	
Snootli Creek tributary	influent	21 ± 2	3 ± 3	2 ± 2	12 :1
	effluent	20 ± 2	6 ± 5	4 ± 2	

[1] number of sites and dates as in Table 28

Table 29. Conuma River, benthic invertebrate abundance ($\bar{x}$±s.d., n=4).
Pre-emergence period (23 May 1979).

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	0.70±0.22	1.88±1.01	4.27±0.45	0.80±0.21
Oligochaeta	0.03±0.01	0.21±0.12	0.30±0.04	0.02±0.02
Hydracarina	0.15±0.05	2.14±0.83	0.59±0.12	0.23±0.10
Copepoda	0.04±0.03	0.09±0.09	0.06±0.05	0.04±0.01
Ostracoda	0.01±0.02	0.64±0.52	0.09±0.06	0.08±0.03
Plecoptera, Trichoptera and Ephemeroptera	0.86±0.02	1.22±0.30	0.83±0.07	1.06±0.35
Total	2.33±0.61	6.35±2.00	6.23±0.45	2.26±0.52

Table 30. Loon Creek, benthic invertebrate abundance ($\bar{x}$±s.d., n=4).
Pre-emergence period (8 Apr. 1980).

Order	Abundance (10^3 organisms·m^{-2}) Site 1	Site 2	Site 3	Site 4
Diptera	3.0± 1.5	17.4± 9.6	15.3± 5.8	3.2± 1.4
Oligochaeta	1.9± 1.4	6.1± 2.1	4.0± 0.7	3.2± 1.8
Hydracarina	1.0± 0.5	2.4± 0.6	1.8± 1.1	0.4± 0.4
Copepoda	2.8± 1.2	2.0± 0.4	2.0± 0.2	1.5± 0.8
Ostracoda	1.3± 0.7	2.6± 0.7	3.3± 1.3	2.4± 2.1
Plecoptera, Trichoptera and Ephemeroptera	6.7± 3.3	9.5± 3.1	9.9± 2.1	3.3± 1.1
Total	19.8± 7.5	45.5±12.2	41.3± 6.3	17.4± 7.2

Table 31. Chemical concentrations of streams with proposed hatchery operations ($\bar{x} \pm$ s.d.).

Parameter ($mg \cdot L^{-1}$)	Chilliwack River	Nicola River	Deadman Creek	Eagle River	Crazy Creek	Finn Creek
pH	7.4 ± 0.1	8.1 ± 0.3	8.0 ± 0.1	7.5 ± 0.3	7.4 ± 0.3	7.0 ± 0.3
alk.	16.7 ± 4.1	87.6 ± 24.6	92.6 ± 17.6	21.6 ± 4.2	19.1 ± 5.1	13.6 ± 6.3
hard.	20 ± 4	101 ± 27	91 ± 20	28.3 ± 4.2	22.7 ± 4.0	15.5 ± 5.1
cond. (us·cm^{-1})	47 ± 10	221 ± 55	200 ± 38	65 ± 12	49 ± 12	35 ± 15
turb. (FTU)	<1	3 ± 1	<1	1 ± 2	1 ± 3	6 ± 9
D.O.	11.5 ± 1.0	11.1 ± 1.6	9.9 ± 1.7	11.9 ± 1.1	12.4 ± 1.0	12.6 ± 0.1
T.R.	39 ± 7	163 ± 51	148 ± 21	54 ± 4	48 ± 8	55 ± 16
N.F.R.	<1	16 ± 33	<1	4 ± 7	6 ± 14	14 ± 24
Ca	7.16 ± 1.71	26.7 ± 6.8	18.7 ± 2.9	9.05 ± 1.43	6.70 ± 1.42	5.28 ± 1.97
Na	0.86 ± 0.13	6.08 ± 2.22	6.48 ± 1.09	1.32 ± 0.32	0.85 ± 0.25	1.07 ± 0.59
Mg	0.63 ± 0.14	8.51 ± 2.73	10.85 ± 3.15	1.39 ± 0.17	1.44 ± 0.13	0.55 ± 0.05
K	0.51 ± 0.06	2.11 ± 1.23	1.59 ± 0.21	0.88 ± 0.05	0.84 ± 0.10	0.49 ± 0.08
SO_4	5.0 ± 1.1	19.3 ± 8.0	10.7 ± 5.1	8.3 ± 1.5	5.0 ± 1.2	3.1 ± 0.3
SiO_2	2.7 ± 0.3	2.6 ± 0.5	5.8 ± 0.7	3.2 ± 0.4	2.9 ± 0.5	3.0 ± 0.7
Cl	<0.5	1.5 ± 0.4	0.6 ± 0.2	1.0 ± 0.6	<0.5	0.7 ± 0.2
F	<0.05	0.08 ± 0.02	<0.05	0.08 ± 0.02	<0.05	0.07 ± 0.06
Fe	0.10 ± 0.09	0.22 ± 0.14	0.10 ± 0.04	0.18 ± 0.23	0.23 ± 0.52	0.32 ± 0.48
Cu	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Zn	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
TOC	1 ± 1	5 ± 2	9 ± 2			
PC	0.169 ± 0.092	0.778 ± 1.091	0.258 ± 0.094	0.273 ± 0.327	0.319 ± 0.609	0.736 ± 1.082
PN	<0.02	0.09 ± 0.06	0.02 ± 0.018	<0.02	<0.02	0.05 ± 0.08
TDN	0.124 ± 0.041	0.355 ± 0.241	0.377 ± 0.033	0.153 ± 0.052	0.201 ± 0.069	0.195 ± 0.025
TON	0.03 ± 0.03	0.32 ± 0.12	0.32 ± 0.09	0.04 ± 0.01	0.05 ± 0.05	0.11 ± 0.11
t-NO_2	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
NO_3	0.097 ± 0.043	0.062 ± 0.051	0.074 ± 0.057	0.107 ± 0.045	0.160 ± 0.061	0.123 ± 0.028
NH_3	0.005 ± 0.004	0.069 ± 0.111	0.003 ± 0.003	0.005 ± 0.003	0.006 ± 0.002	0.005 ± 0.002
t-PO_4	0.007 ± 0.005	0.102 ± 0.139	0.014 ± 0.003	0.006 ± 0.010	0.011 ± 0.027	0.018 ± 0.032
N:P ratio	21:1	1.4:1	4.4:1	36:1	53:1	20:1
No. dates	25	17	13	6	6	3

Table 32. Eagle River and Finn Creek, benthic invertebrate abundance ($\bar{x}\pm$s.d., n=4).
Pre-emergence period (9 Apr. 1980).

Order	Abundance (10^3 organisms·m^{-2}) Eagle River	 Finn Creek
Diptera	33.6±35.1	7.8± 4.2
Oligochaeta	<0.1	0.5± 1.1
Hydracarina	0.7± 0.5	<0.1
Copepoda	<0.1	0
Ostracoda	<0.1	<0.1
Plecoptera, Trichoptera and Ephemeroptera	3.0± 0.9	43.0±23.5
Total	37.7±35.6	51.8±27.6

Table 33. Hatchery food supply rates, effluent nutrient loadings, and maximum fish biomass.

Hatchery	Mean daily rate of food supply[1] (kg·d^{-1})	Mean effluent ammonia load[2] (kg·d^{-1})	Mean effluent phosphate load[2] (kg·d^{-1})	Maximum fish biomass in hatchery[3] (kg)
Quinsam	226	4.17 0.28 [4]	1.42 1.14 [4]	29,700
Puntledge				
1979	58.1	1.65	0.65	6,800
1980	69.3			12,000
Big Qualicum	167.2	5.58	2.12	22,000
Capilano	78.0	1.02	0.37	10,600

[1] Calculated from daily rates of food supplied between 1 Oct. 1978 and 10 Sep. 1979.

[2] Excludes phosphate or ammonia loads attributable to background levels.

[3] Prior to release of fish during spring.

[4] Additional load from Cold Creek water used to rear fish.

Table 34. Linear correlation of periphyton chlorophyll *a* accumulations with selected physical and chemical parameters.

A. Quinsam River (May to October, 1979)

Parameter[1]	Correlation coefficient				
	Site 1	Site 2	Site 3	Site 4	All sites
flow	-0.45**	-0.42**	-0.36*	-0.22	-0.31**
PO_4	0.09	0.03	-0.38*	-0.13	-0.03
NO_3	0.32	0.08	0.26	0.45*	0.33**
NH_3	-0.07	0.60**	-0.24	-0.09	-0.11
TON	0.15	0.36*	0.56**	0.56**	-0.07
SiO_2	-0.17	0.07	-0.39*	-0.32	-0.15
temp.	-0.30	0.50**	-0.60**	-0.52**	-0.09

B. Puntledge River (March to July, 1980)

Parameter[1]	Correlation coefficient				
	Site 1	Site 2	Site 3	Site 4	All sites
flow	-0.51*	-0.50*	-0.48*	-0.25	-0.28*
NO_3	-0.56*	0.42	0.03	0.38	0.22
TON	0.54*	0.20	0.25	-0.20	-0.04
SiO_2	-0.16	-0.11	0.48*	-0.18	0.15
temp.	0.07	-0.25**	-0.46*	-0.25	0.14
t-PO_4, NH_3	no significant correlation at any site				

Table 34 (cont'd).

C. Big Qualicum River (June to September, 1979)

Parameter[1]	Correlation coefficient Site 1	Site 2	Site 3	All sites
PO_4	-0.35	-0.32	-0.77**	-0.05
NO_3	-0.45	-0.78*	-0.54	-0.46**
NH_3	0.25	-0.87**	-0.60*	-0.14
flow, TON, SiO_2, temp.	no significant correlation at any site			

D. Capilano River (May to October, 1979)

Parameter[1]	Correlation coefficient Site 1	Site 2	Site 3	Site 4	All sites
flow	-0.71**	-0.22	-0.36	-0.30	-0.18
PO_4	0.26	-0.15	0.68**	-0.41	0.29*
NO_3	0.33	0.09	0.45	-0.31	0.26*
SiO_2	0.14	0.10	0.75**	0.23	0.35**
temperature	0.28	0.17	0.48*	0.49	0.27*
NO_3, TON	no significant correlation at any site				

[1] Parameters:
flow = flow over artificial substrates on sampling date
SiO_2 = silica concentration
temp. = temperature at time of sampling
* = significant at $p<0.05$
** = significant at $p<0.01$

Table 35. Multiple regression of periphyton chlorophyll a levels with selected physical and chemical parameters[1].

A. Quinsam River (May to October, 1979)

	Partial coef[2]	R^2 x 100[3]
Site 1	flow = -0.74	42.4
	SiO_2 = -0.55	
Site 2	NH_3 = 0.49	46.2
	temp = 0.34	
Site 3	NO_3 = 0.82	86.5
	TON = 0.50	
	PO_4 = -0.57	
	flow = -0.39	
Site 4	TON = 0.56	31.4
All sites	NO_3 = 0.42	25.0
	PO_4 = -0.22	
	flow = -0.32	

B. Puntledge River (March to July, 1980)

	Partial coef[2]	R^2 x 100[3]
Site 1	NO_3 = -0.55	57.8
	flow = -0.48	
Site 2	flow = -0.64	70.6
	NO_3 = 0.59	
	PO_4 = -0.48	
Site 3	SiO_2 = 0.48	23.0
Site 4	none significant	
All sites	flow = -0.28	7.8

C. Big Qualicum River (June to September, 1979)

	Partial coef[2]	R^2 x 100[3]
Site 1	none significant	
Site 2	NH_3 = -0.67 NO_3 = -0.51	98.4
Site 3	PO_4 = -0.77	59.3
All sites	NO_3 = 0.46	21.2

D. Capilano River (May to October, 1979)

	Partial coef[2]	R^2 x 100[3]
Site 1	flow = -0.71	50.4
Site 2	none significant	
Site 3	SiO_2 = 1.00 NO_3 = -0.47	72.2
Site 4	none significant	
All sites	SiO_2 = 0.53 TON = -0.03	17.6

[1] parameters abbreviated as in table 34
[2] partial coef = partial normalized coefficient
[3] R^2x100, R= multiple coefficient

Table 36. Abundance of periphyton species upstream and downstream of the major hatcheries.

Species	Streams[1]						
	Q		P		C		B
	p	r	p	r	p	r	r
BACILLARIOPHYCEAE							
Synedra ulna	--	0	+	+			+?
S. rumpens	--	0	++	0	++	++	+?
Tabellaria fenestrata	-		-	-			
T. flocculosa	-				-	-	
Diatoma vulgare	++	++					++
D. hiemale v. *mesodon*			+	++	++	+	
Hannaea arcus			++	++	++	+	?
Fragilaria crotonensis			++	+			
F. capucina v. *mesolepta*	++	++	++	+			
F. construens							++
F. vaucheriae	0		+	+	++		+
Cocconeis placentula	+	+					++
Achnanthes minutissima	0	+	0	0	++	++	0?
A. linearis v. *pusilla*	-	-	++	+			0?
A. affinis	++	+			++	+	
A. lanceolata	++	++					+
A. gibberula					+	+	
Cymbella minuta	++	++	+	+	++	++	++
C. minuta v. *silesiaca*	++	++	++	+			++
C. sinuata	+	++					0?
Gomphonema angustatum	--	-	+	++	++	++	--?
G. parvulum	-	-	+	++			--?
G. truncatum	--						
G. subclavatum			+	++			
Navicula pelliculosa	++	++					?
Nitzschia palea	++	++	++	++	++	+	++?
N. cf. *fonticola*	++	++	++	++			++?
N. kuetzingiana			++	++			
N. acicularis							+
N. sp. (faint)			++	++	++	++	
CYANOPHYCEAE							
Chamaesiphon sp. (nat)[2]							--
Lyngbya digueti	-	-					-
Phormidium autumnale (nat)[2]		+		++		++	-
Plectonema notatum	++	++	++	++	++	++	++

Table 36 (cont'd).

Species	Streams[1] Q p	 r	 P p	 r	 C p	 r	 B r
CHLOROPHYCEAE							
Bulbochaete spp.			+	+	--	--	
Cladophora glomerata (nat)[2]		+					++
Draparnaldia plumosa	+		+		++		
Geminella minor			+		--	--	
Mougeotia spp.			-	-	--	--	
Oedogonium spp.	-		++	+	+		
Spirogyra spp.	-		+	+	-		
Stigeoclonium stagnatile	+	+	+	++	+		+
Tetraspora sp.	+						
Ulothrix tenuissima	++	++	++	++	++	++	++
U. zonata	++	++	++	++	++	++	++
Zygnema spp.			-		-		
CHRYSOPHYCEAE							
Hydrurus foetidus				++		++	

---

[1] Q=Quinsam, P=Puntledge, C=Capilano, B=Big Qualicum, p=pools, r=riffles

[2] nat = natural substrates only

++ = large increase downstream of hatchery
+ = small increase downstream of hatchery
0 = no change downstream of hatchery
- = small decrease downstream of hatchery
-- = large decrease downstream of hatchery
? = not enough data or unsure of trends
= not common on that river

Table 37. Similarity of diatom assemblages among sites in the major hatchery streams.

Pools	Similarity Index (x 100)[1]																	
	Capilano				Puntledge				Quinsam				Big Qualicum					
	C1	C2	C3[2]	C4	P1	P2	P3	P4	Q1	Q2	Q3	Q4	B1	B2	B3	B4[2]	B5[2]	B6[2]
C1																		
C2	79																	
C3	83	93																
C4	92	90	94															
P1	22	19	22	23														
P2	80	74	78	84	26													
P3	89	78	83	93	24	91												
P4	93	77	82	94	22	87	99											
Q1	85	77	82	91	24	87	93	94										
Q2	36	45	41	38	9	69	42	39	46									
Q3	70	72	70	74	16	92	91	79	78	85								
Q4	75	78	76	80	18	92	84	92	85	75	97							
riffles																		
C1																		
C2	66																	
C3[2]	--	--																
C4	84	57	--															
P1	28	34	--	54														
P2	82	56	--	95	52													
P3	72	44	--	79	42	92												
P4	67	54	--	99	54	98	86											
Q1	83	52	--	99	52	95	78	99										
Q2	41	31	--	48	25	46	38	47	49									
Q3	61	46	--	73	38	70	57	72	74	93								
Q4	41	35	--	48	25	48	38	48	49	97	99							
B1	30	19	--	23	15	37	37	35	34	90	80	88						
B2	26	17	--	20	15	36	42	32	28	80	64	70	81					
B3	31	23	--	24	19	43	47	39	35	70	59	58	63	95				
B4[2]	45	46	--	34	27	52	48	51	50	93	90	91	87	77	69			
B5[2]	45	46	--	35	27	56	54	53	51	90	86	84	83	81	77	98		
B6[2]	25	23	--	18	13	32	35	30	25	89	75	84	94	89	78	92	90	
	C1	C2	C3	C4	P1	P2	P3	P4	Q1	Q2	Q3	Q4	B1	B2	B3	B4[2]	B5[2]	B6[2]

---

[1] similarity indices calculated from mean annual percent abundances

[2] no data for C3 riffles, sporadic summer data for B4, B5, B6

Fig. 1 Site Location Map

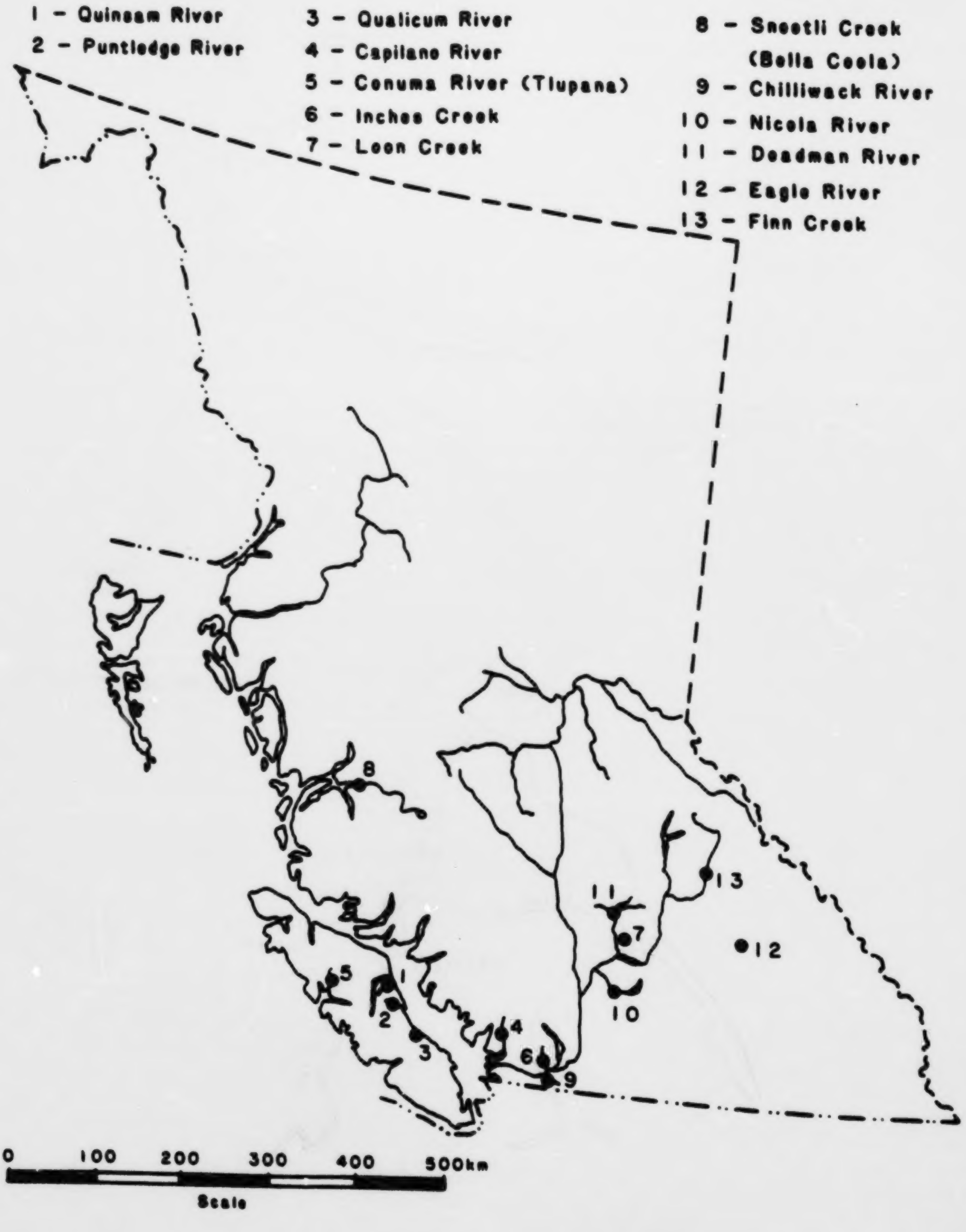

1 - Quinsam River
2 - Puntledge River
3 - Qualicum River
4 - Capilano River
5 - Conuma River (Tlupana)
6 - Inches Creek
7 - Loon Creek
8 - Snootli Creek (Bella Coola)
9 - Chilliwack River
10 - Nicola River
11 - Deadman River
12 - Eagle River
13 - Finn Creek
1
2
3
4
5
6
7
8
9
10
11
12
13
0
100
200
300
400
500km
Scale

Fig. 2(a) Quinsam River Study Sites

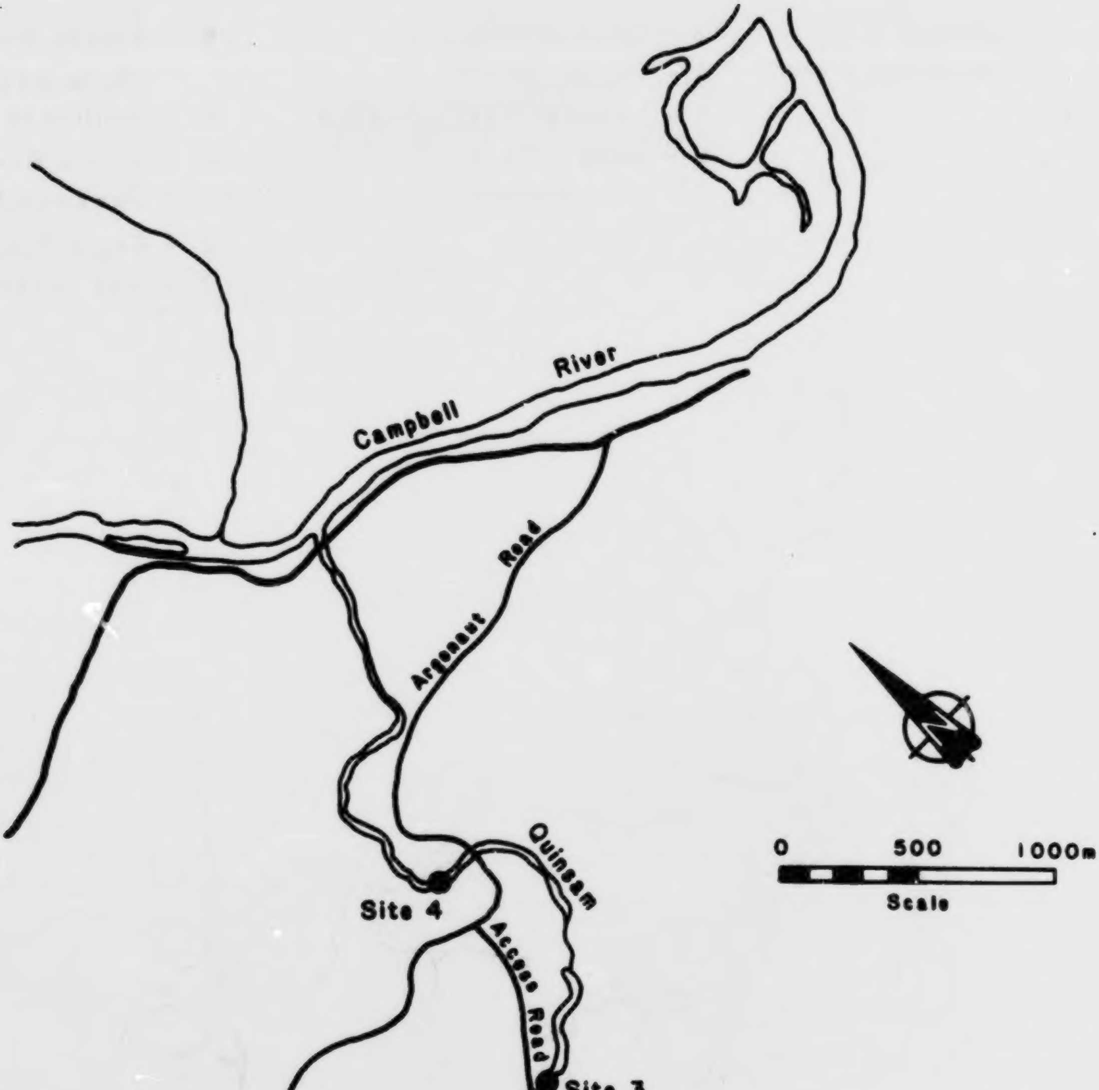

Campbell River
Argonaut Road
Quinsam
Site 4
Access Road
Site 3
Site 2
Hatchery Outfall
Hatchery
Site 1
River
Cold Creek
0
500
1000m
Scale

Fig. 2(b) Puntledge River Study Sites

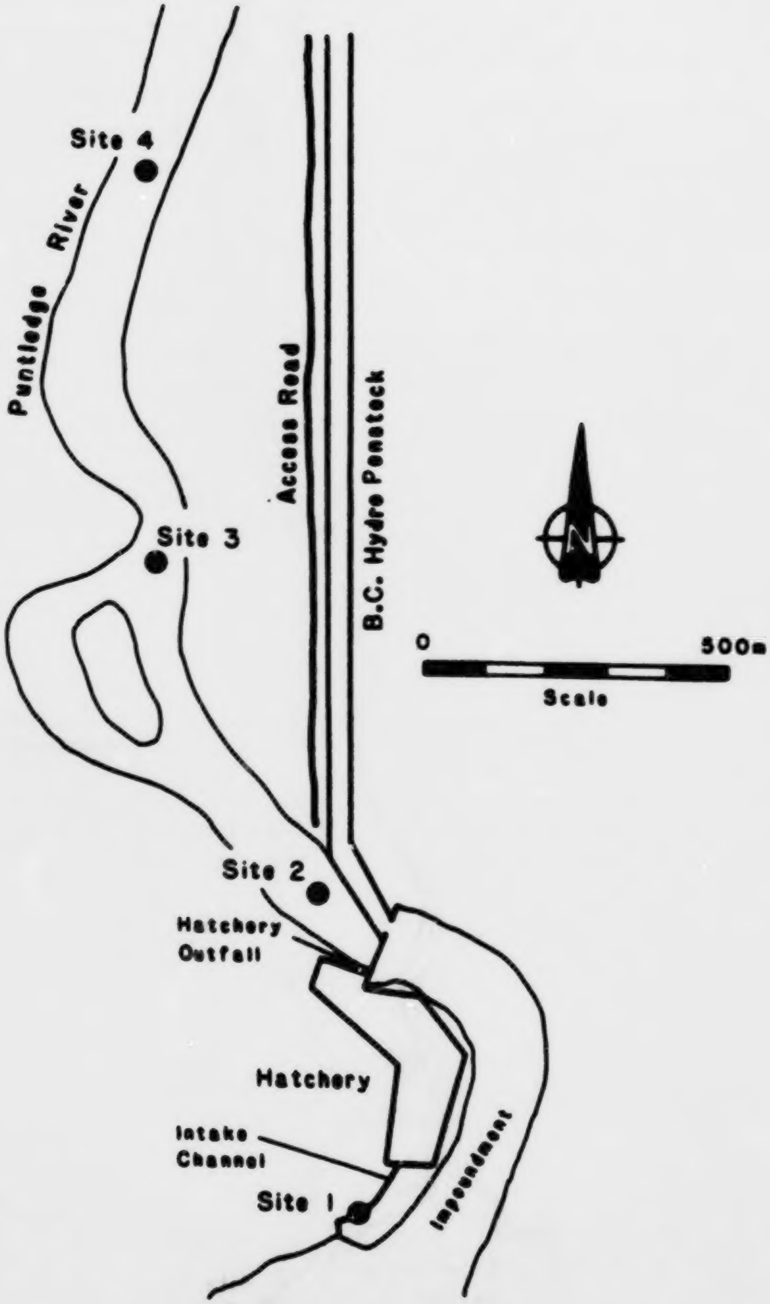

Site 4
Puntledge River
Access Road
B.C. Hydro Penstock
Site 3
N
0
500m
Scale
Site 2
Hatchery Outfall
Hatchery
Intake Channel
Site 1
Impoundment

Fig. 2(c) Big Qualicum River Study Sites

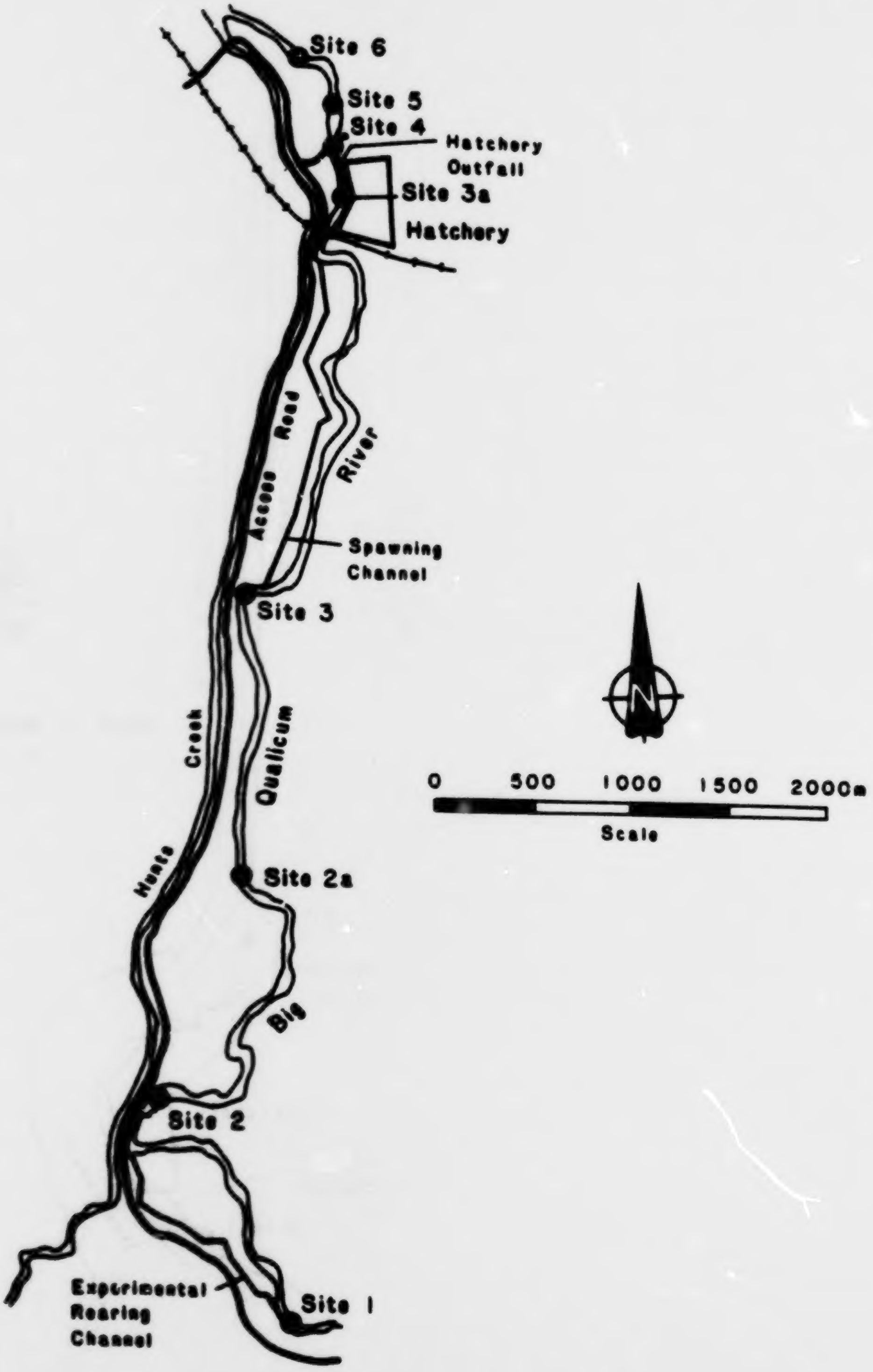

Site 6
Site 5
Site 4
Hatchery Outfall
Site 3a
Hatchery
Access Road
River
Spawning Channel
Site 3
Qualicum
Creek
Hunts
Site 2a
Big
Site 2
Experimental Rearing Channel
Site 1
N
0
500
1000
1500
2000m
Scale

Fig. 2(d) Capilano River Study Sites

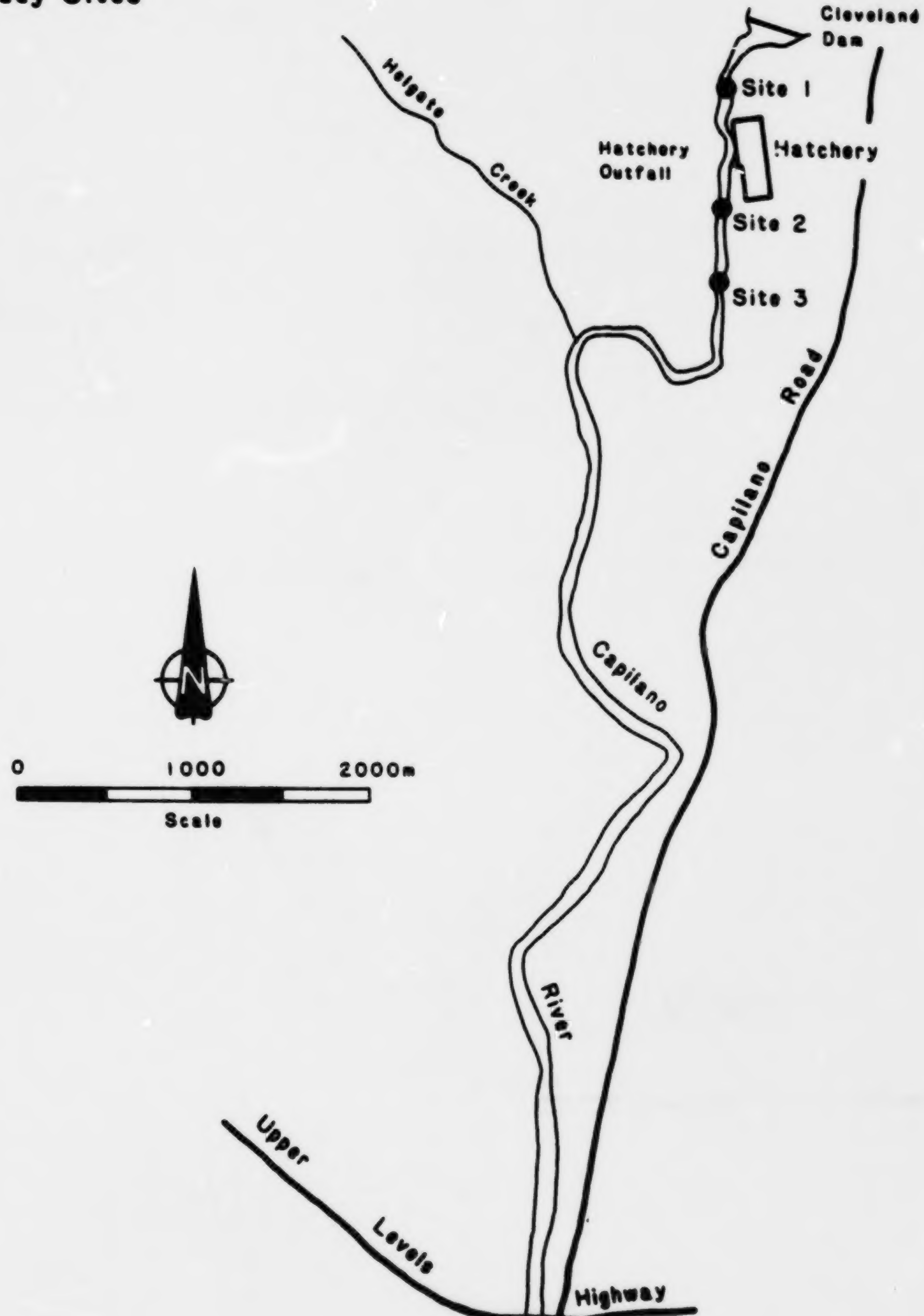

Cleveland Dam
Helgate Creek
Site 1
Hatchery Outfall
Hatchery
Site 2
Site 3
Capilano Road
N
0
1000
2000m
Scale
Capilano
River
Upper Levels Highway
Site 4

Fig. 2(e) Conuma River
Study Sites

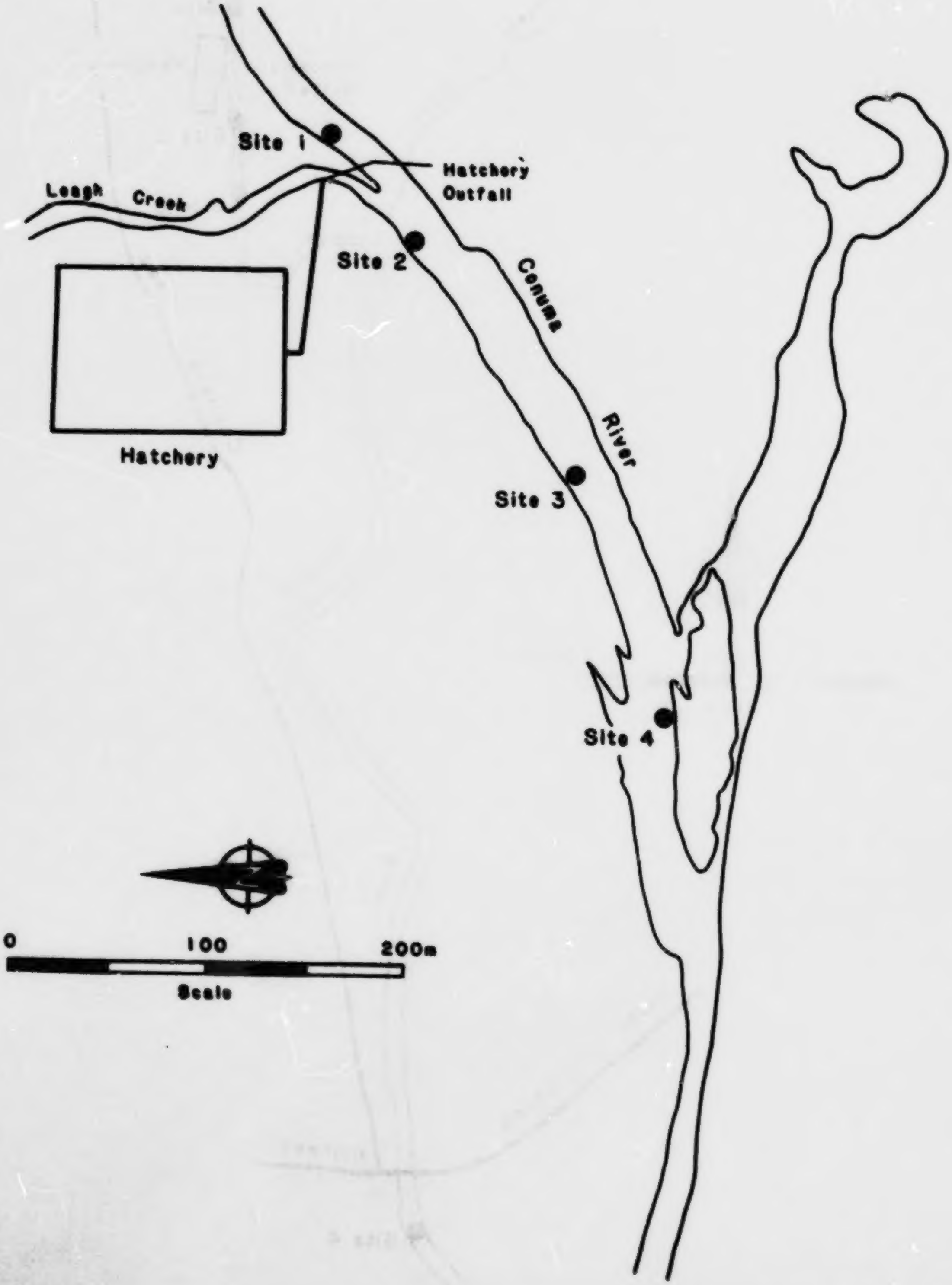

Site 1
Hatchery Outfall
Leagh Creek
Site 2
Conuma
River
Hatchery
Site 3
Site 4
0
100
200m
Scale

Fig. 2(f) Inches Creek Study Sites

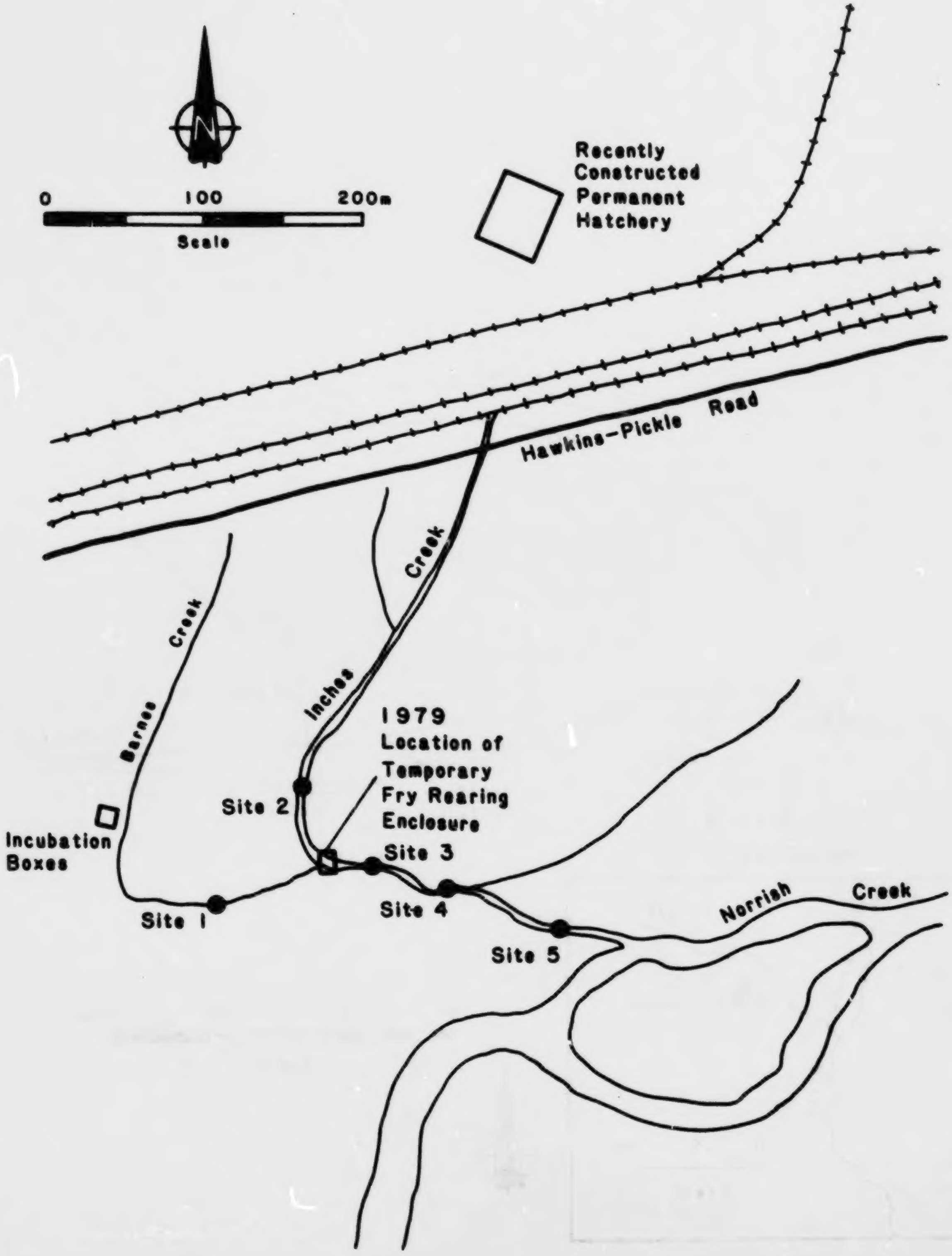

0
100
200m
Scale
Recently Constructed Permanent Hatchery
Hawkins-Pickle Road
Inches Creek
Barnes Creek
1979 Location of Temporary Fry Rearing Enclosure
Incubation Boxes
Site 1
Site 2
Site 3
Site 4
Site 5
Norrish Creek

Fig. 2(g) Loon Creek Study Sites

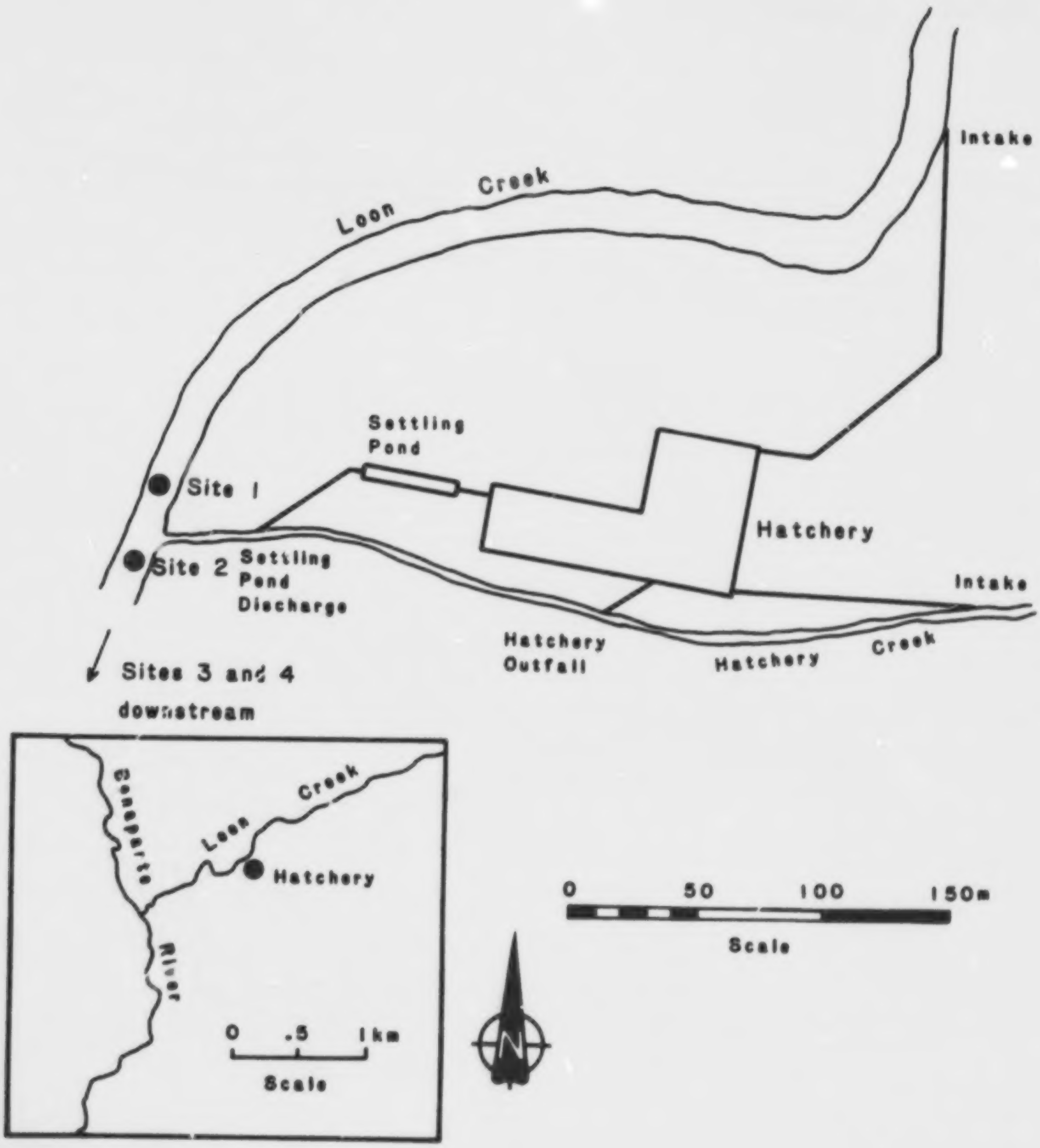
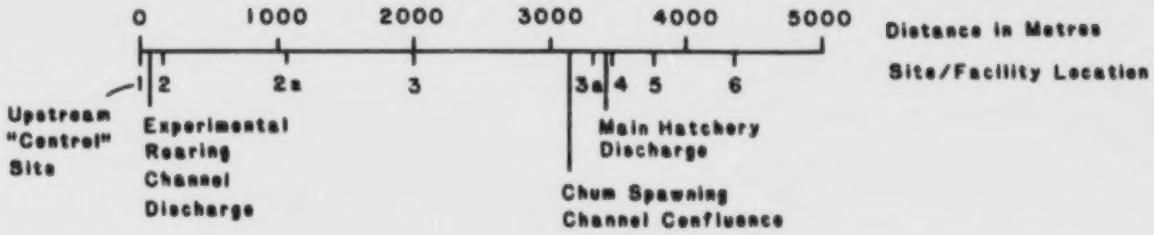

Intake
Loon Creek
Settling Pond
Site 1
Hatchery
Site 2
Settling Pond Discharge
Intake
Hatchery Outfall
Hatchery Creek
Sites 3 and 4 downstream
Bonaparte River
Loon Creek
Hatchery
0 .5 1km
Scale
0 50 100 150m
Scale
N

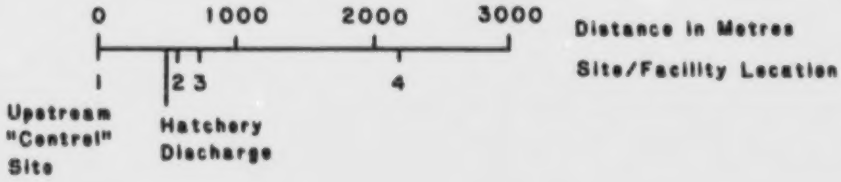
Fig. 3 Major Hatchery Rivers Studied

Schematic Site Locations

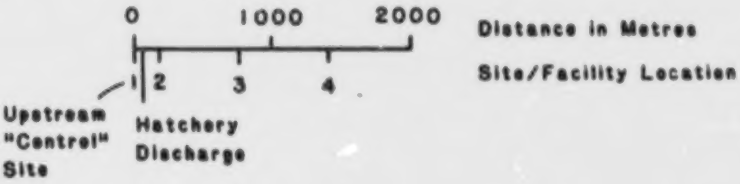
Big Qualicum River


0
1000
2000
3000
4000
5000
Distance in Metres
Site/Facility Location
1
2
2a
3
3a
4
5
6
Upstream "Control" Site
Experimental Rearing Channel Discharge
Main Hatchery Discharge
Chum Spawning Channel Confluence

Quinsam River


0
1000
2000
3000
Distance in Metres
Site/Facility Location
1
2
3
4
Upstream "Control" Site
Hatchery Discharge

Puntledge River


0
1000
2000
Distance in Metres
Site/Facility Location
1
2
3
4
Upstream "Control" Site
Hatchery Discharge

Capilano River

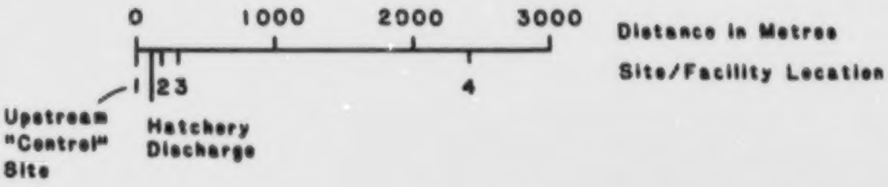
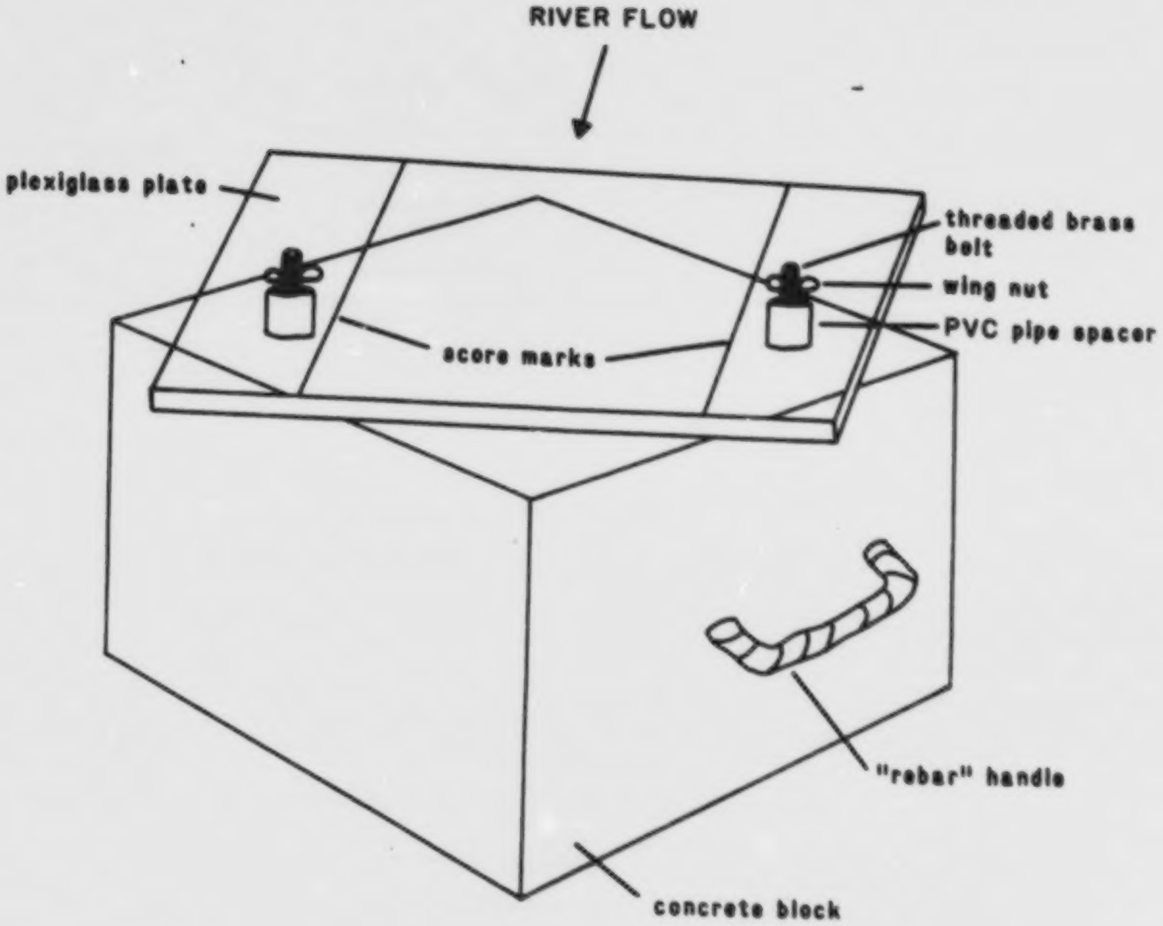

0
1000
2000
3000
Distance in Metres
Site/Facility Location
1
2
3
4
Upstream "Control" Site
Hatchery Discharge

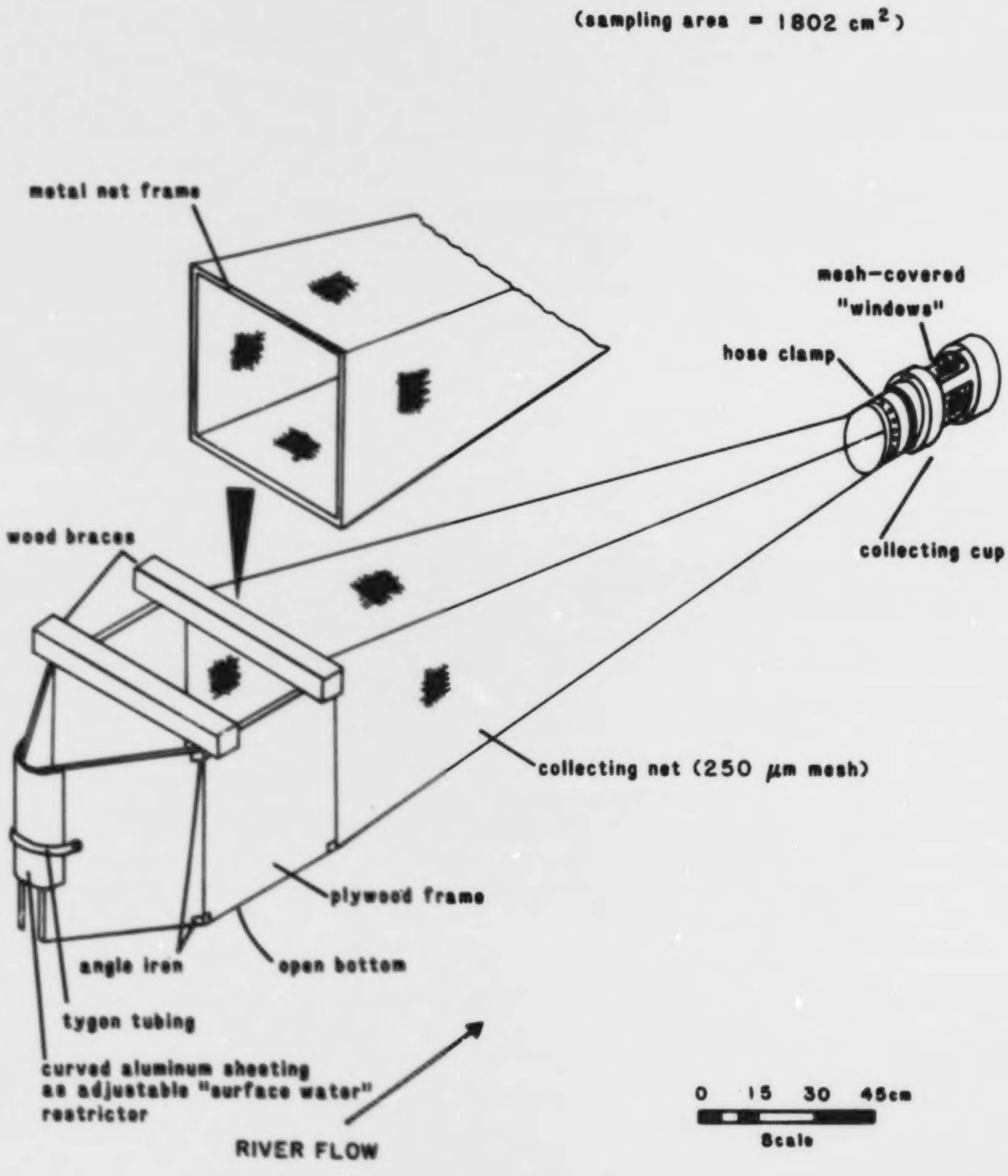
Fig. 4 Periphyton Artificial Substrate Sampler


RIVER FLOW
plexiglass plate
threaded brass bolt
wing nut
PVC pipe spacer
score marks
"rebar" handle
concrete block

concrete block = 30 cm x 30 cm x 20 cm
plexiglass plate = 30 cm x 20 cm x .75 cm
sampling area between scored lines = 400 cm^2

adapted from Stockner and Shortreed, 1976

Fig. 5 Benthic Invertebrates Sampler


(sampling area = 1802 cm²)
metal net frame
mesh-covered "windows"
hose clamp
collecting cup
wood braces
collecting net (250 μm mesh)
plywood frame
angle iron
open bottom
tygon tubing
curved aluminum sheeting as adjustable "surface water" restrictor
RIVER FLOW
0 15 30 45cm
Scale

adapted from Mundie, 1971

Fig. 6 Quinsam River

Water Temperatures

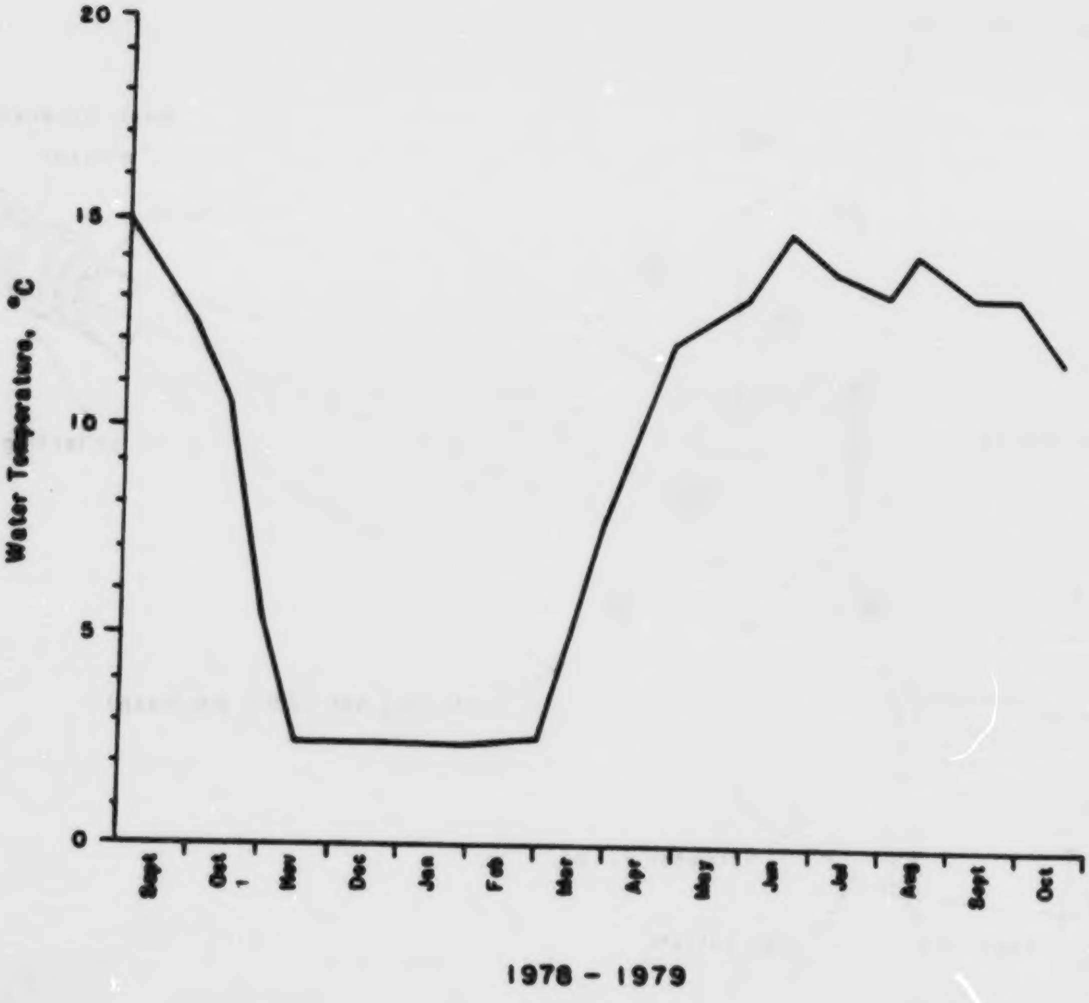


Fig. 7 Quinsam River

Water Discharge (recorded at Site 1)

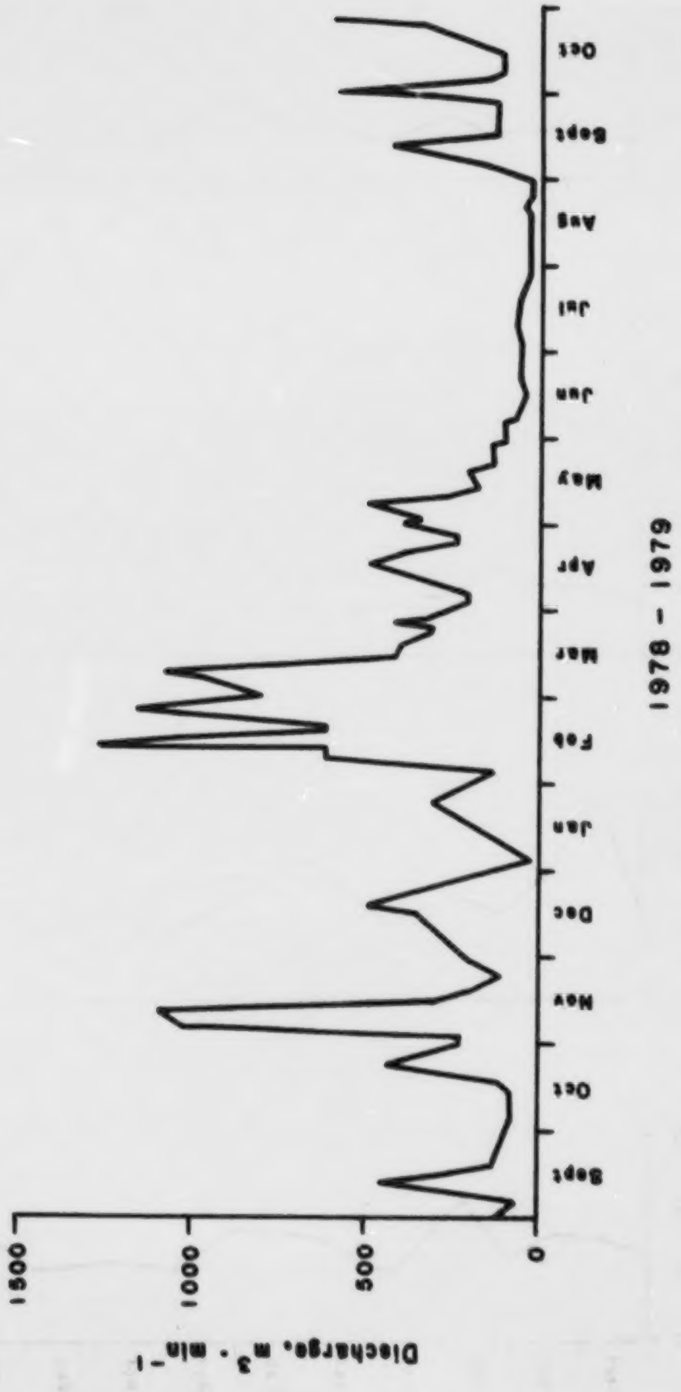
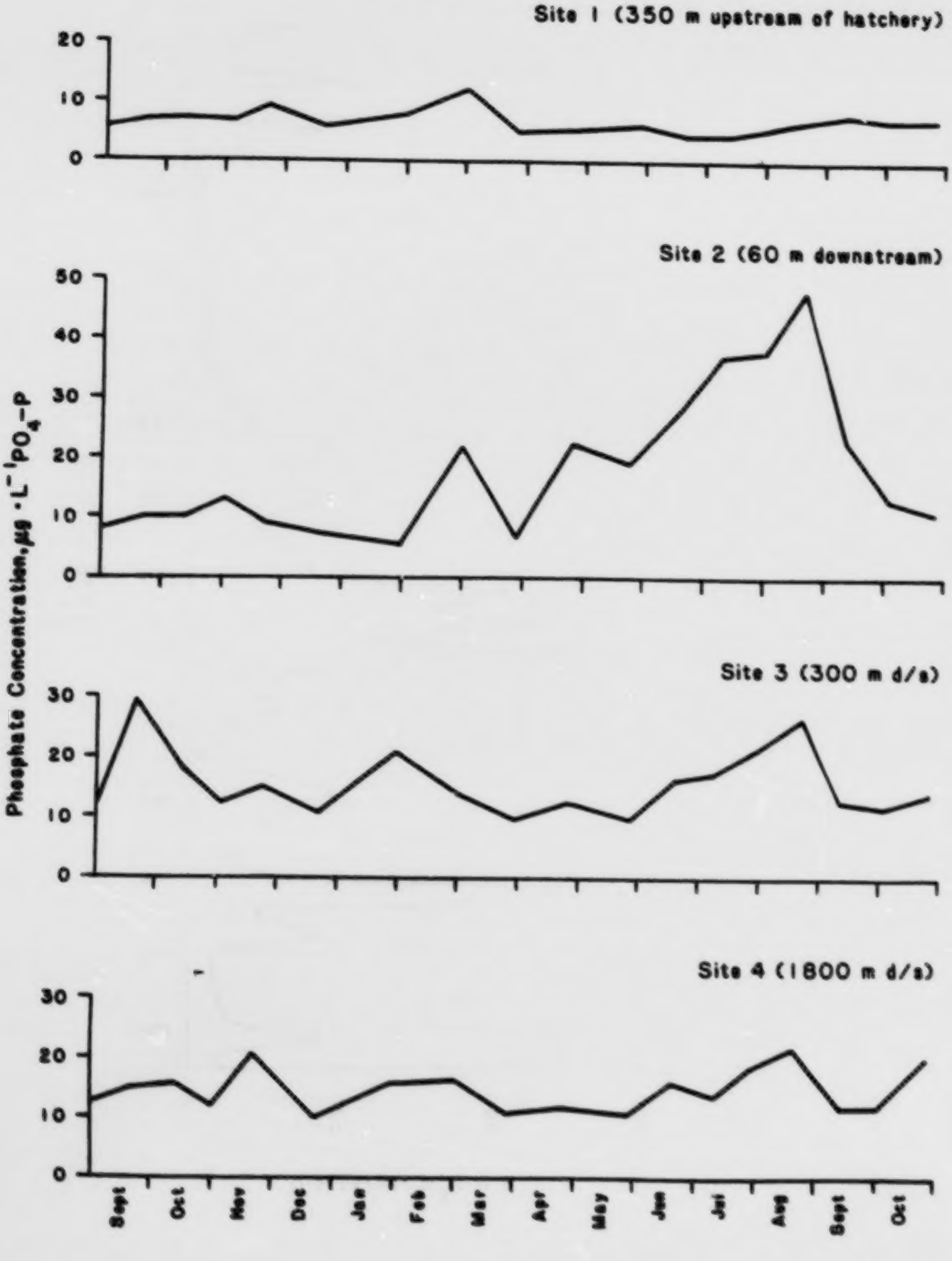


Fig. 8 Quinsam River

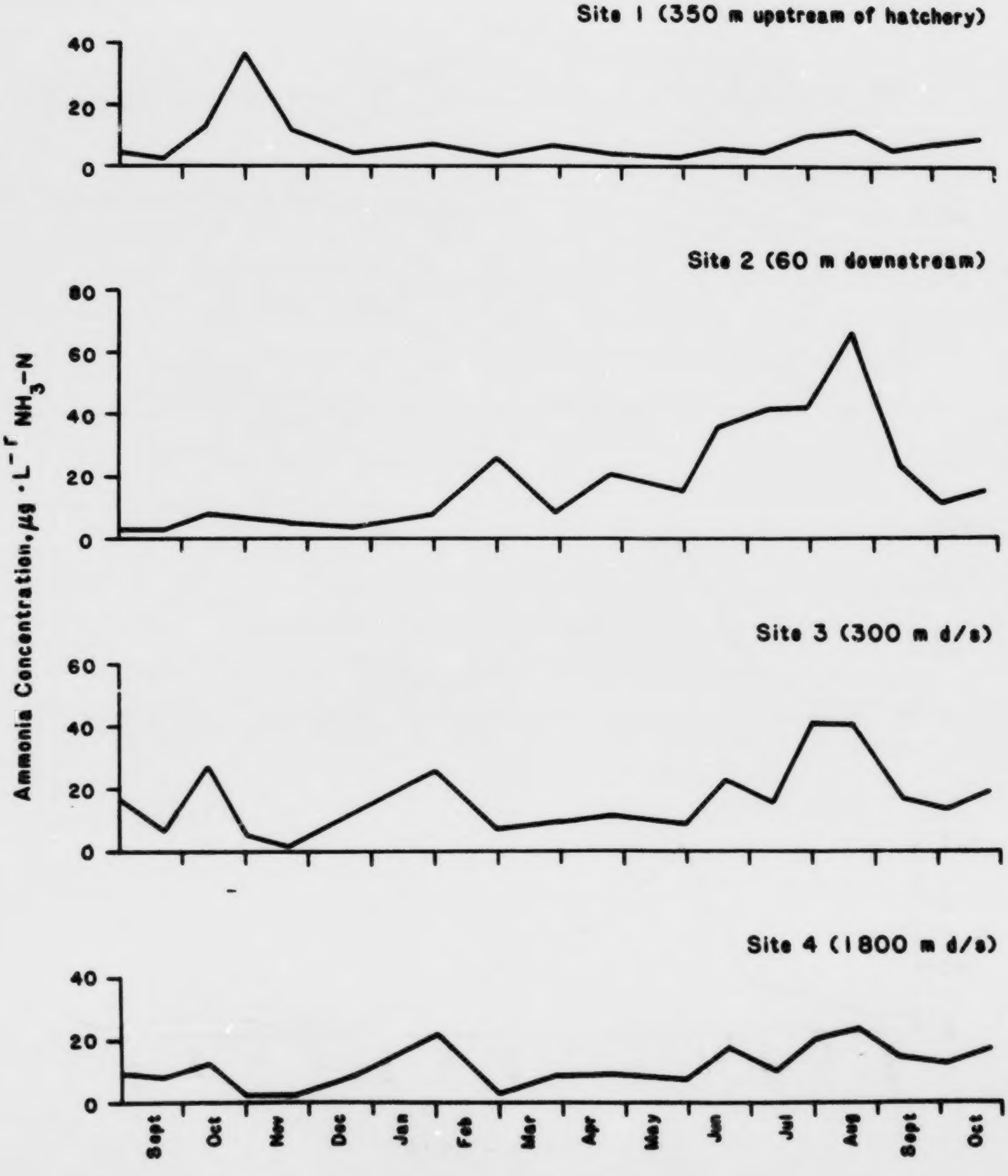
Total Phosphate Concentrations



1978 - 1979

Fig. 9 Quinsam River

Total Ammonia Concentrations – Filtered Samples



1978 – 1979

Fig. 10 Quinsam River

Total Nitrate Concentrations - Filtered Samples

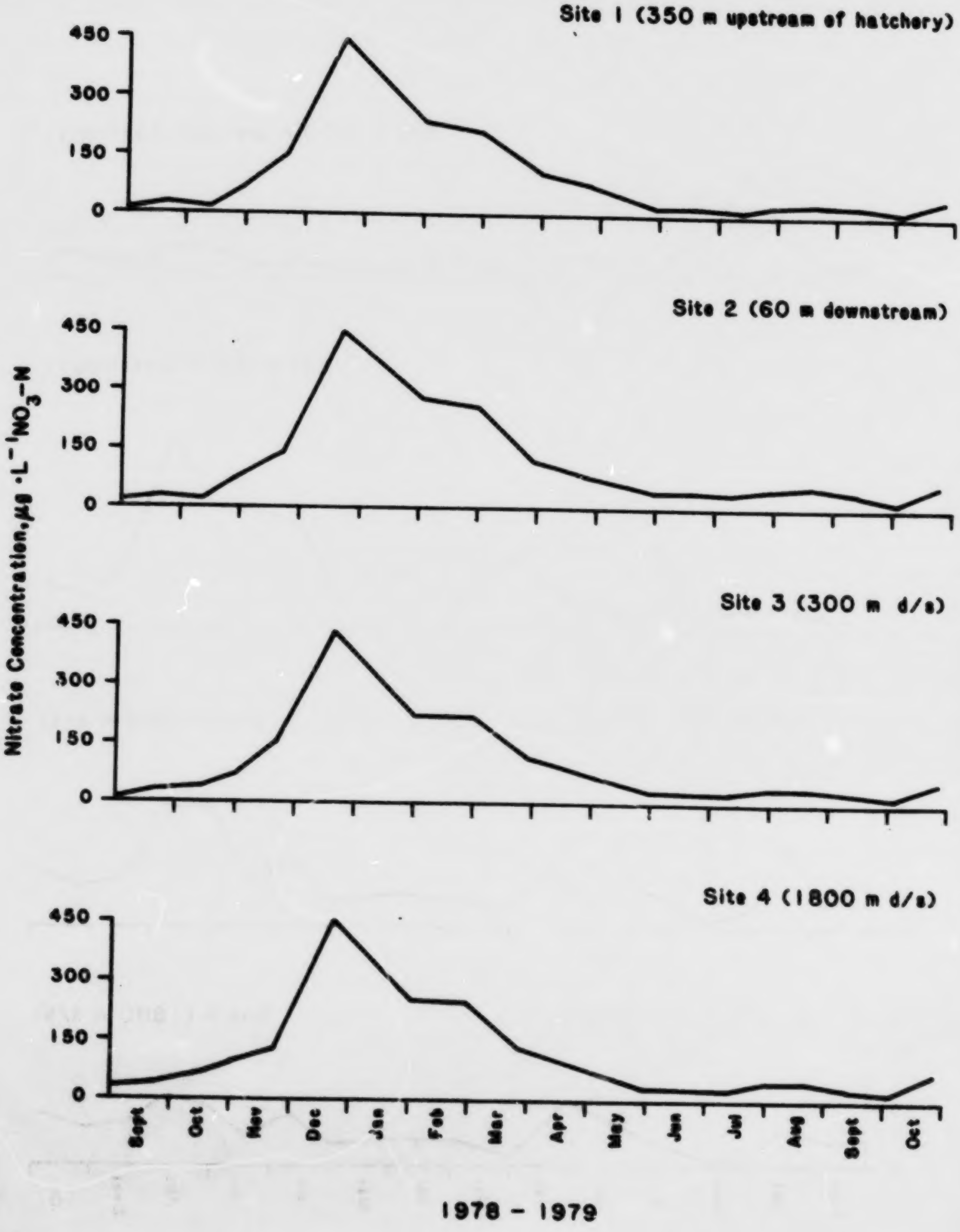
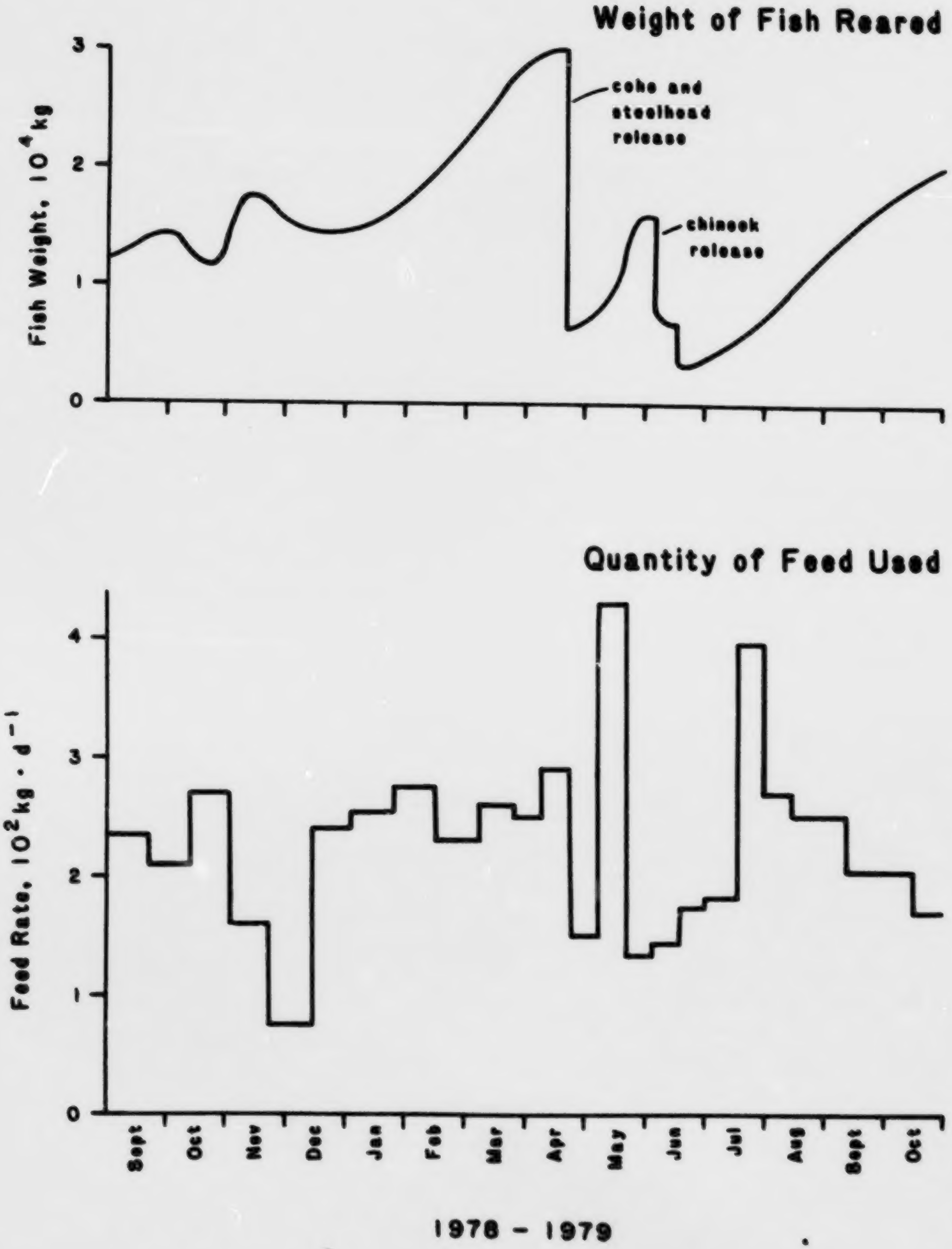


Fig. 11 Quinsam River
Fish Rearing Information



Weight of Fish Reared

Quantity of Feed Used

Fig. 12(a) Quinsam River – Pool Sites

Periphyton Chlorophyll a

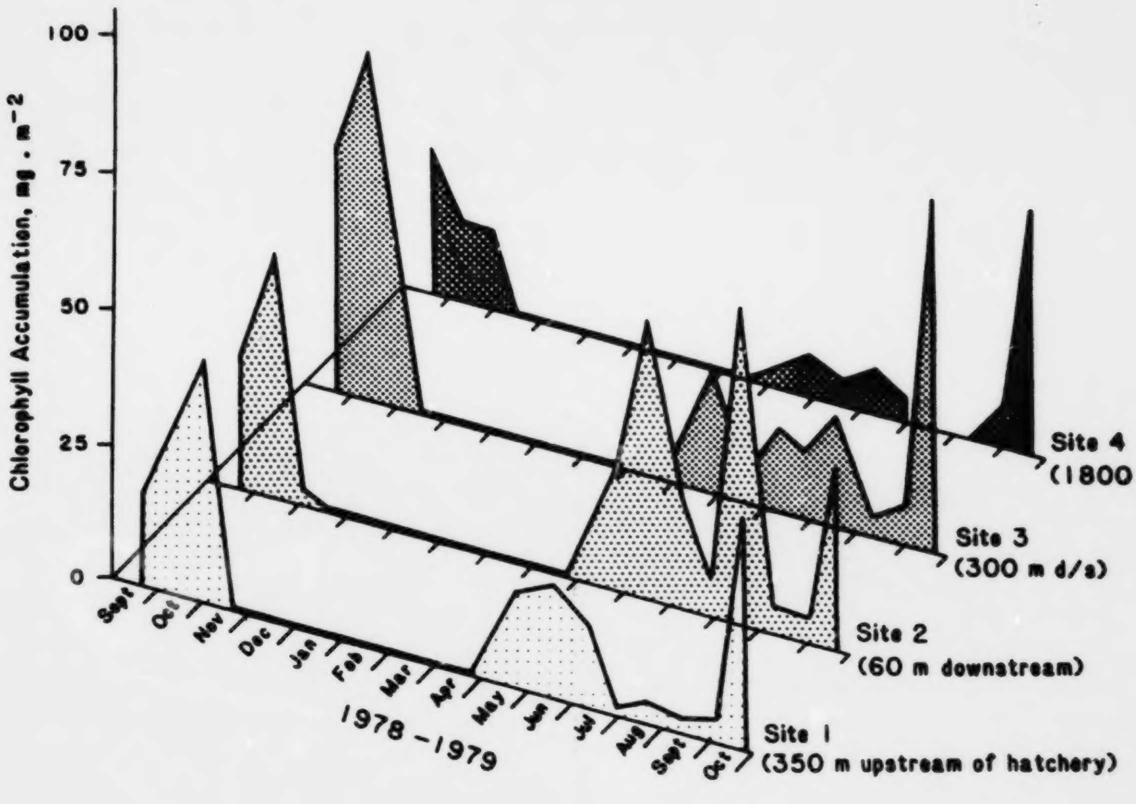


Fig. 12(a) cont. Quinsam River – Pool Sites
Periphyton Organic Weight

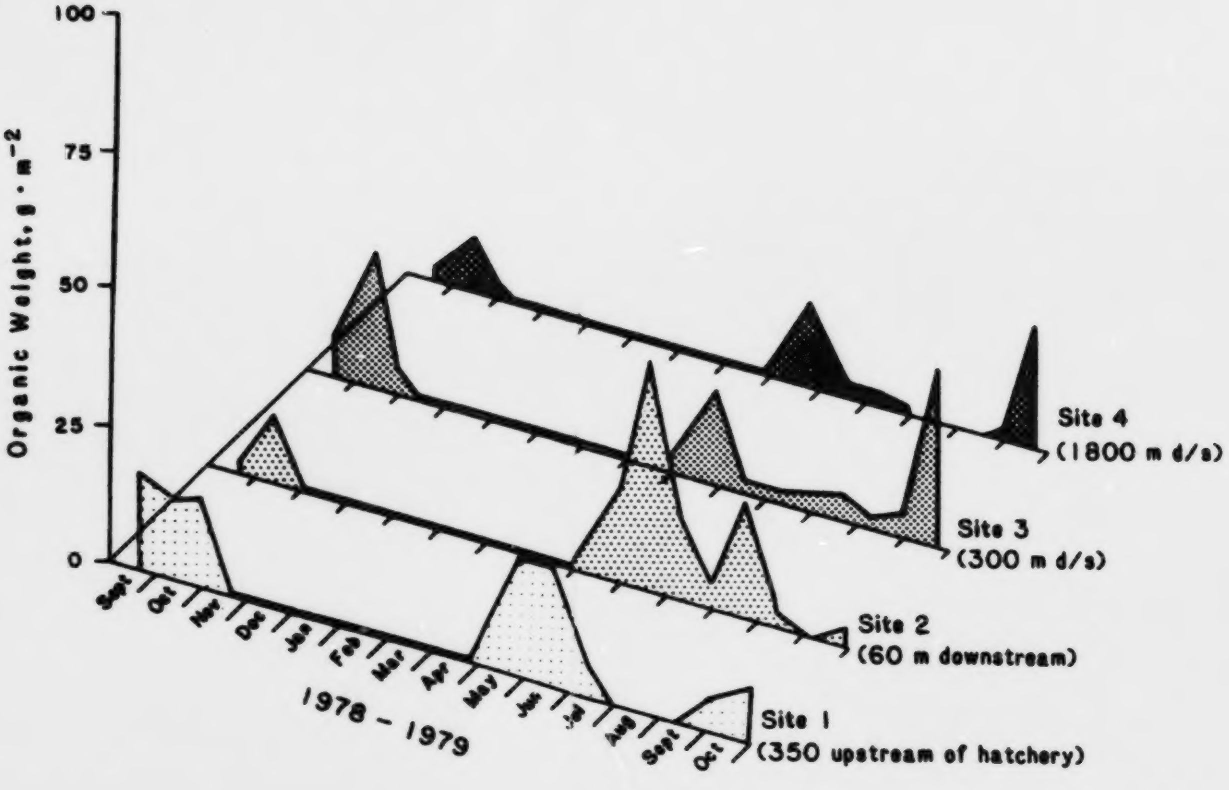


Fig. 12(b) Quinsam River – Riffle Sites

Periphyton Chlorophyll a

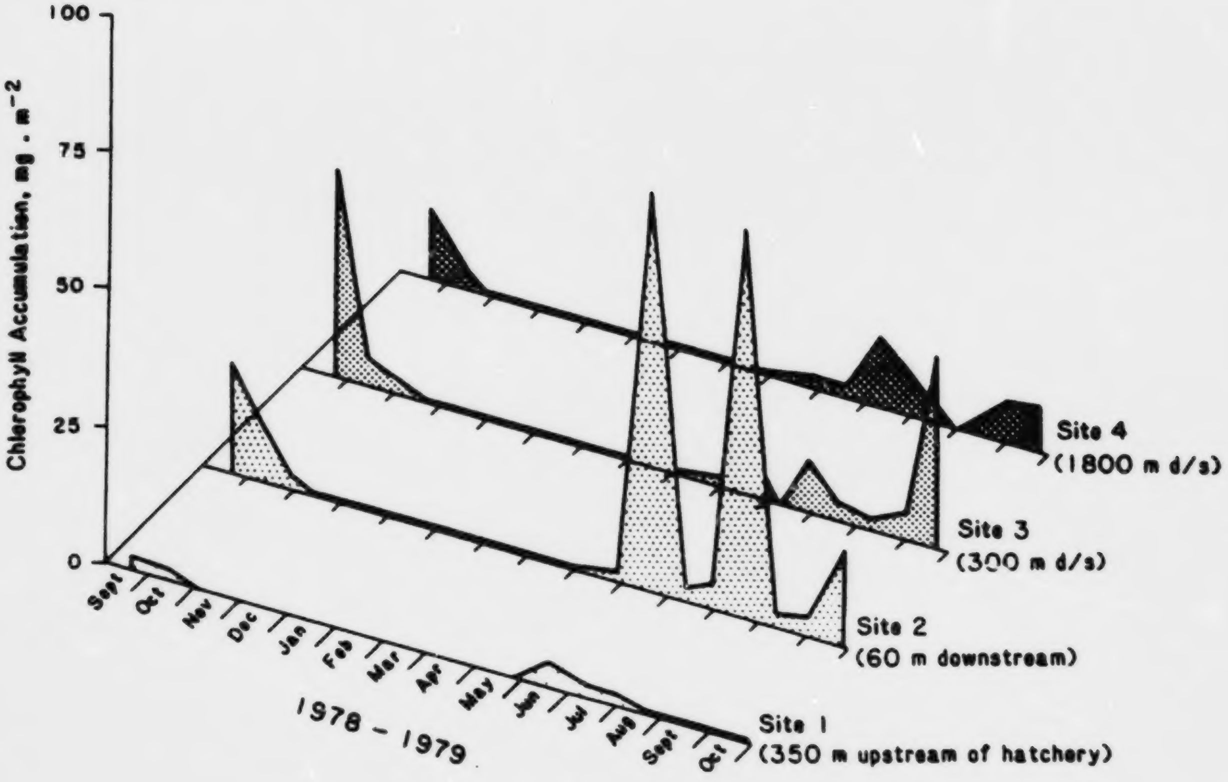


Fig. 12(b) cont. Quinsam River – Riffle Sites
Periphyton Organic Weight

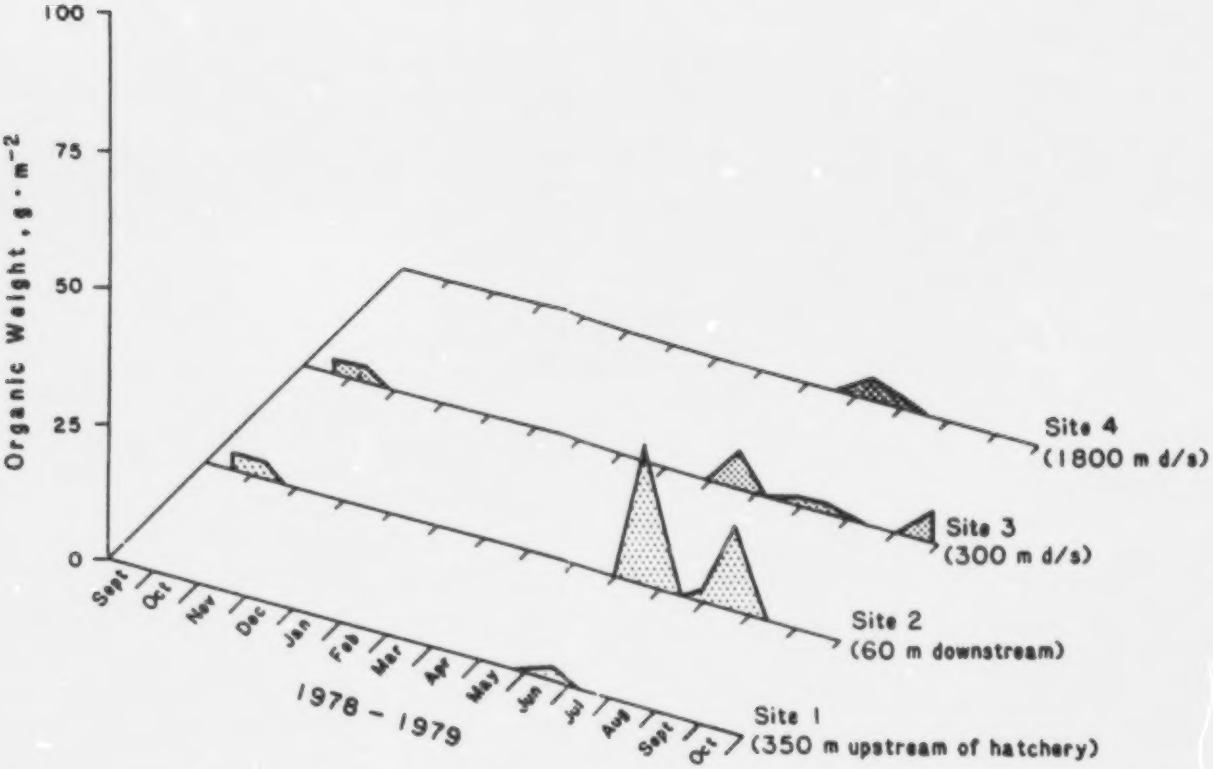


Fig. 13(a) Quinsam River – Pool Sites
Periphyton Species Composition, % Abundance

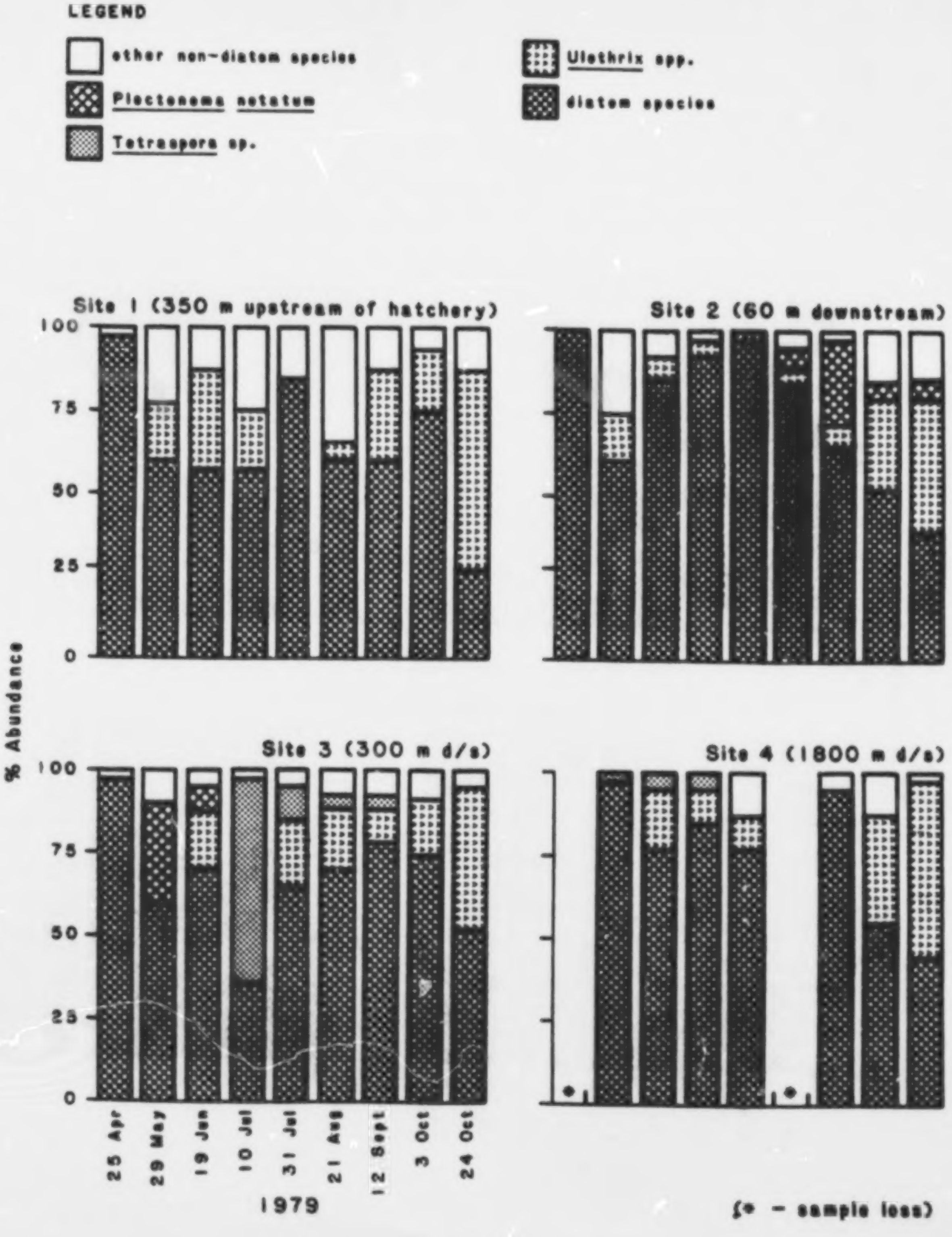


Fig. 13(b) Quinsam River – Riffle Sites

Periphyton Species Composition, % Abundance

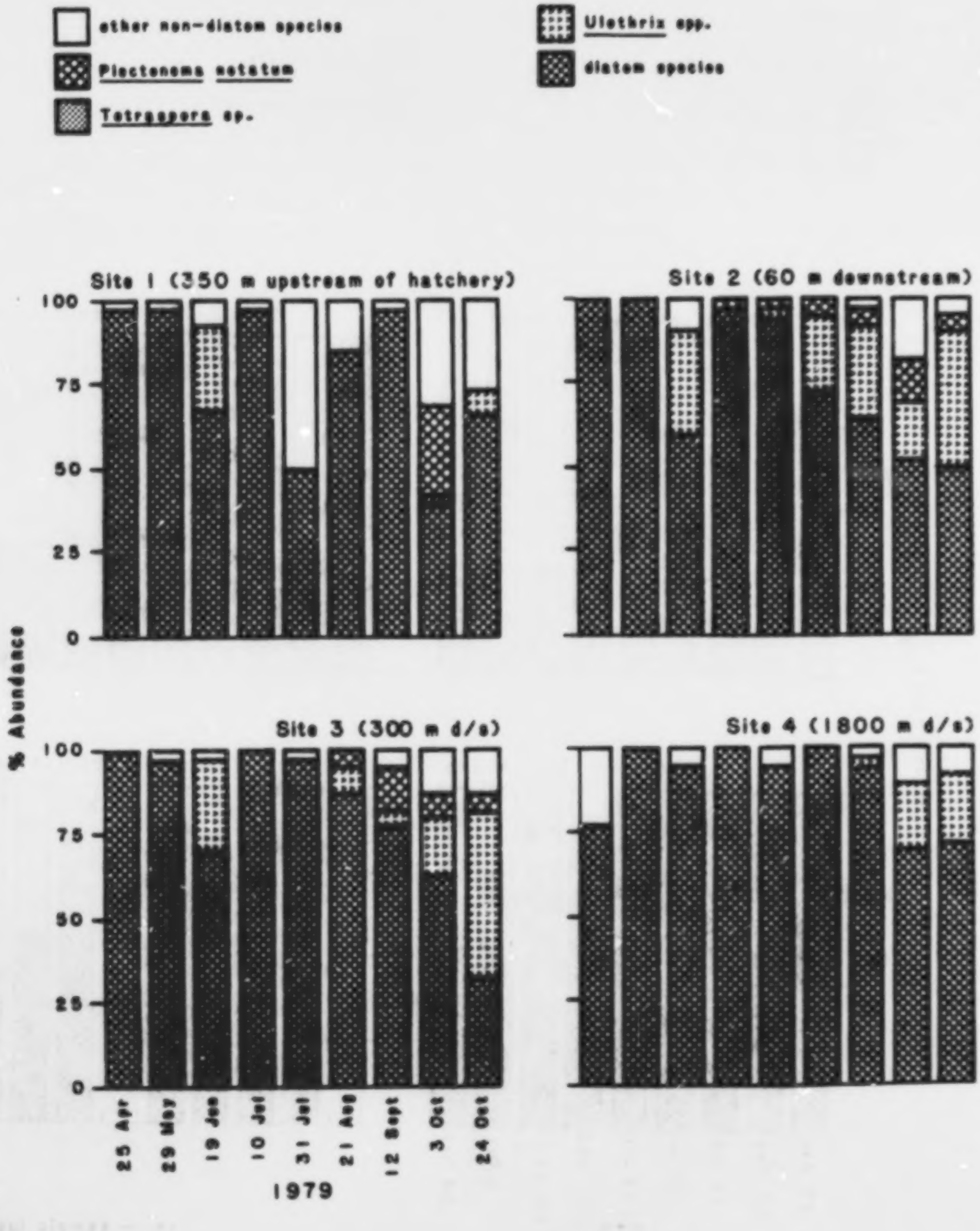
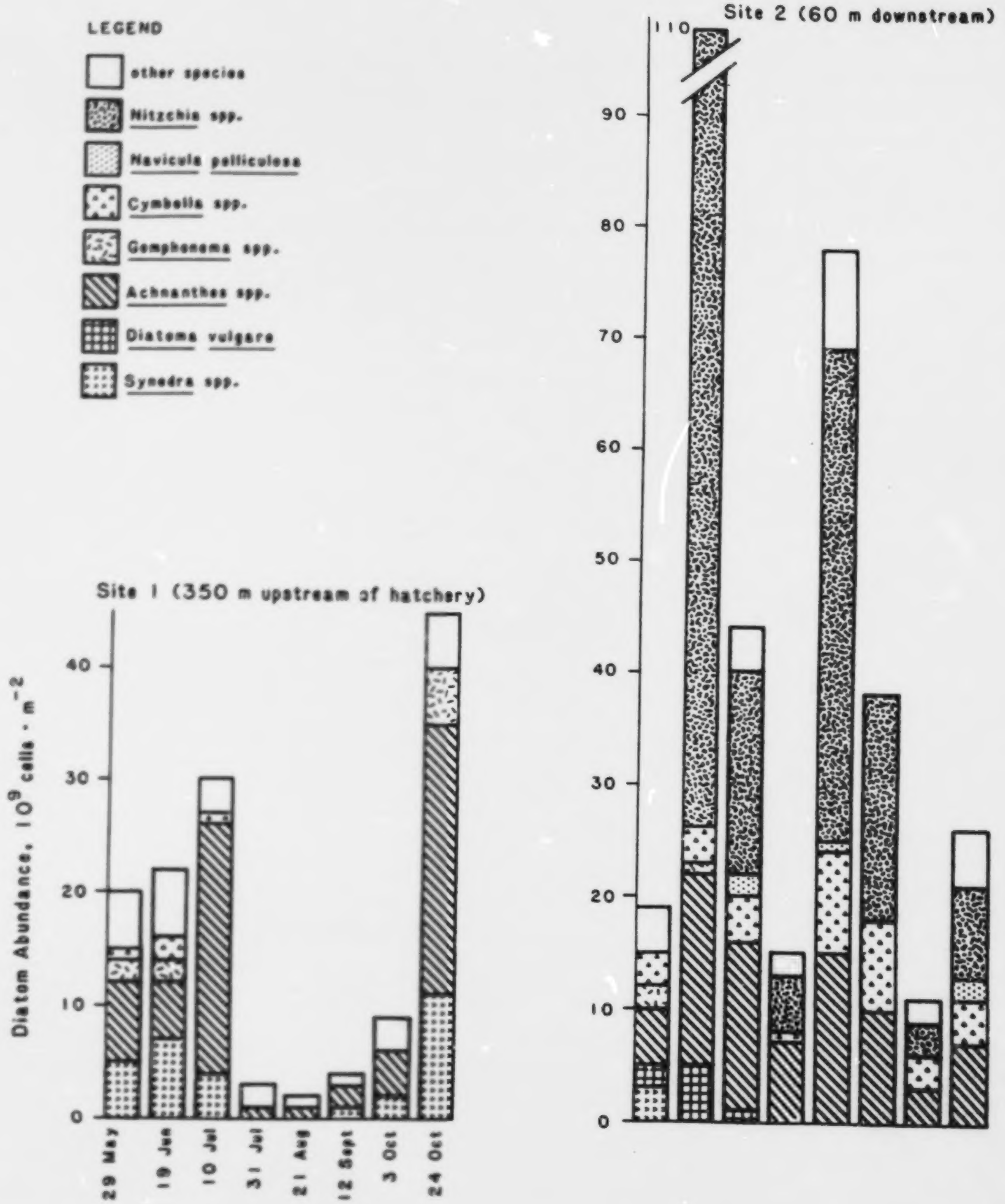
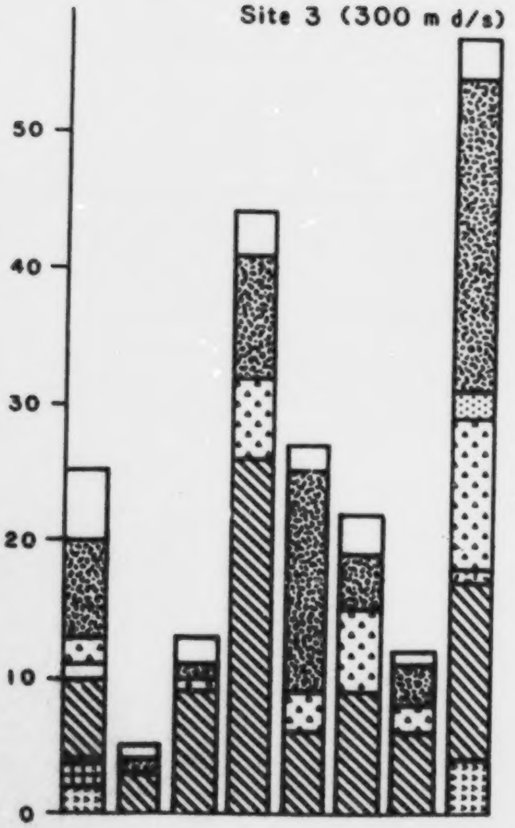
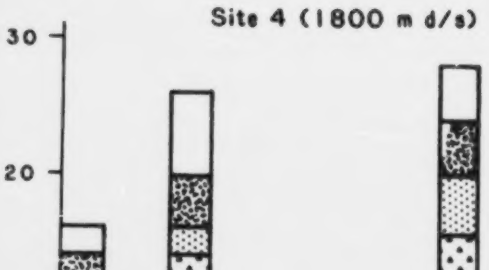


Fig. 14(a) Quinsam River – Pool Sites
Diatom Assemblage Size and Composition

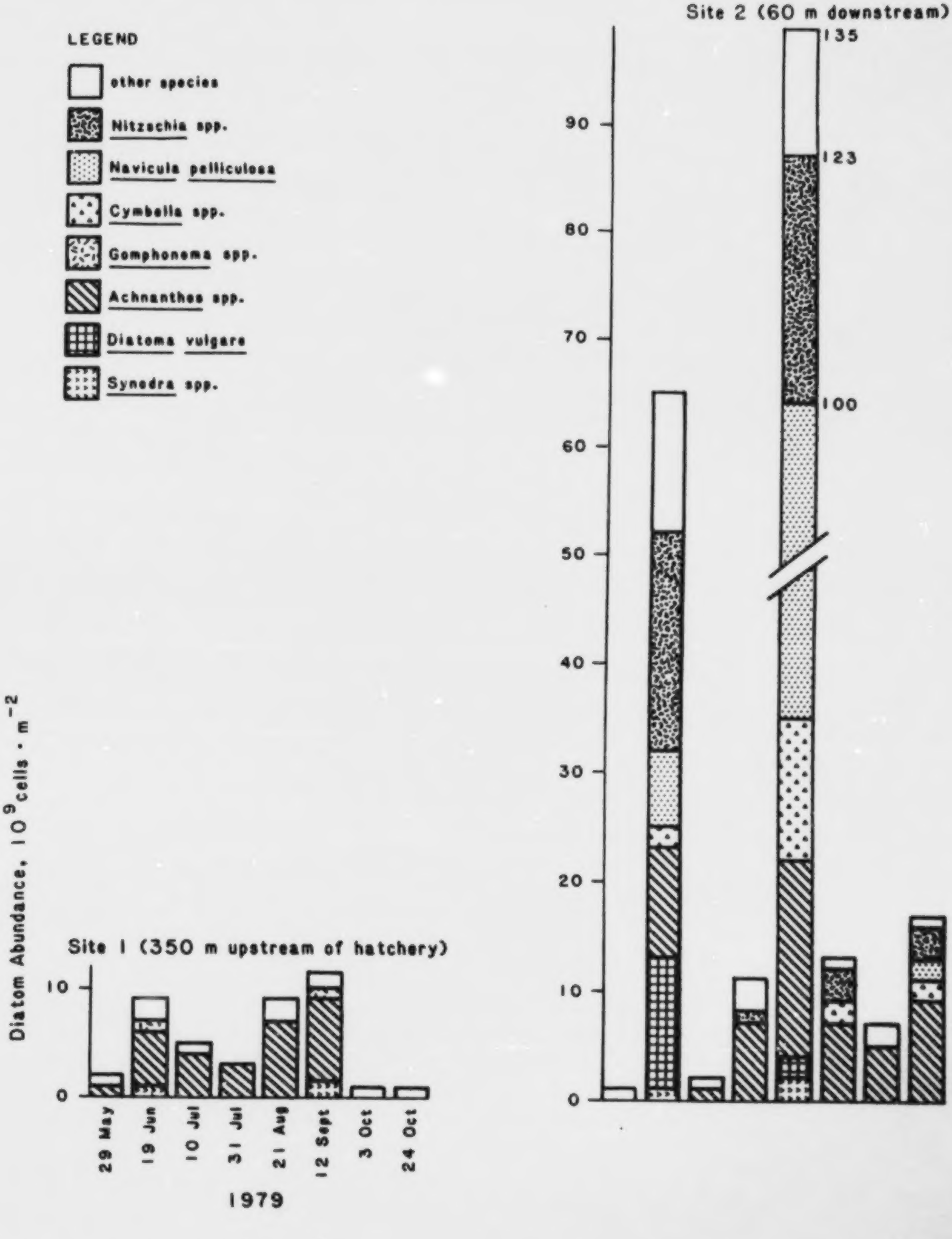


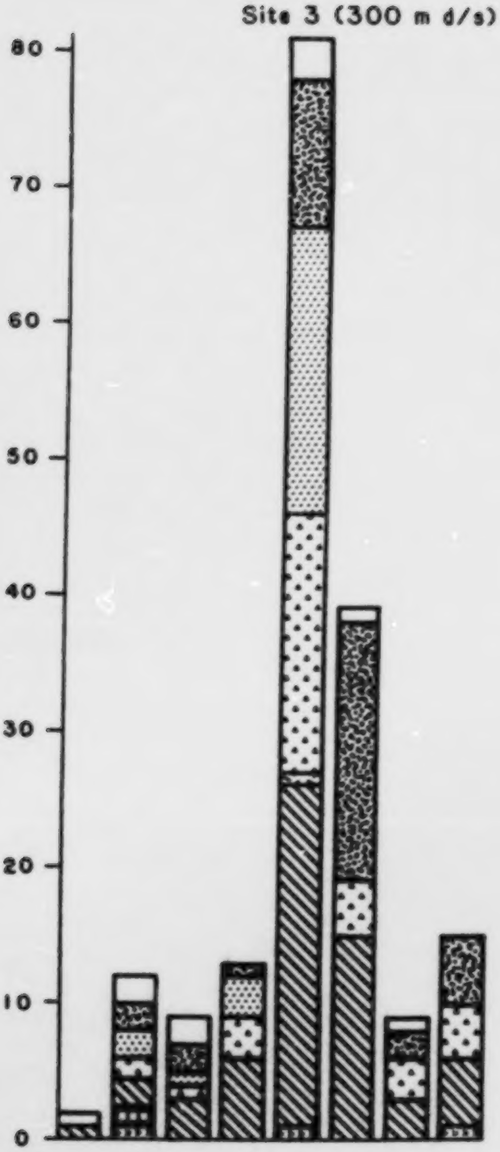




(* - sample losses)

Fig. 14(b) Quinsam River — Riffle Sites
Diatom Assemblage Size and Composition




Site 3 (300 m d/s)
80
70
60
50
40
30
20
10
0

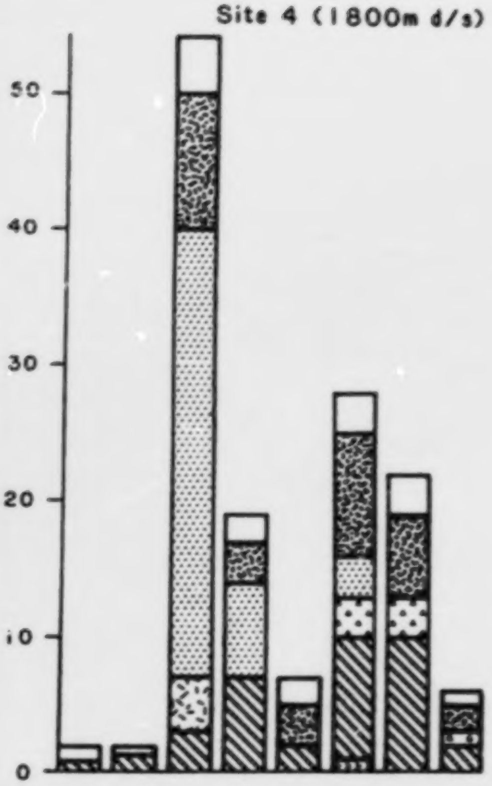

Site 4 (1800m d/s)
50
40
30
20
10
0

Fig. 15 Quinsam River
Benthic Invertebrate Abundance

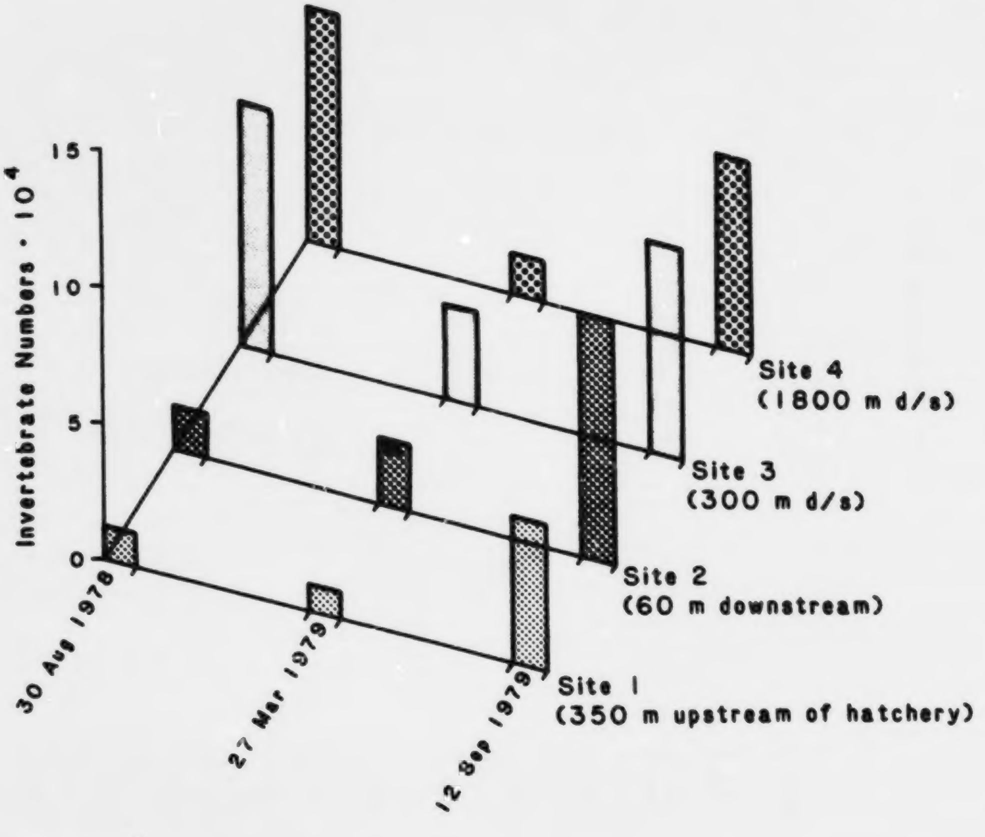


Fig. 16 Puntledge River
Water Temperatures

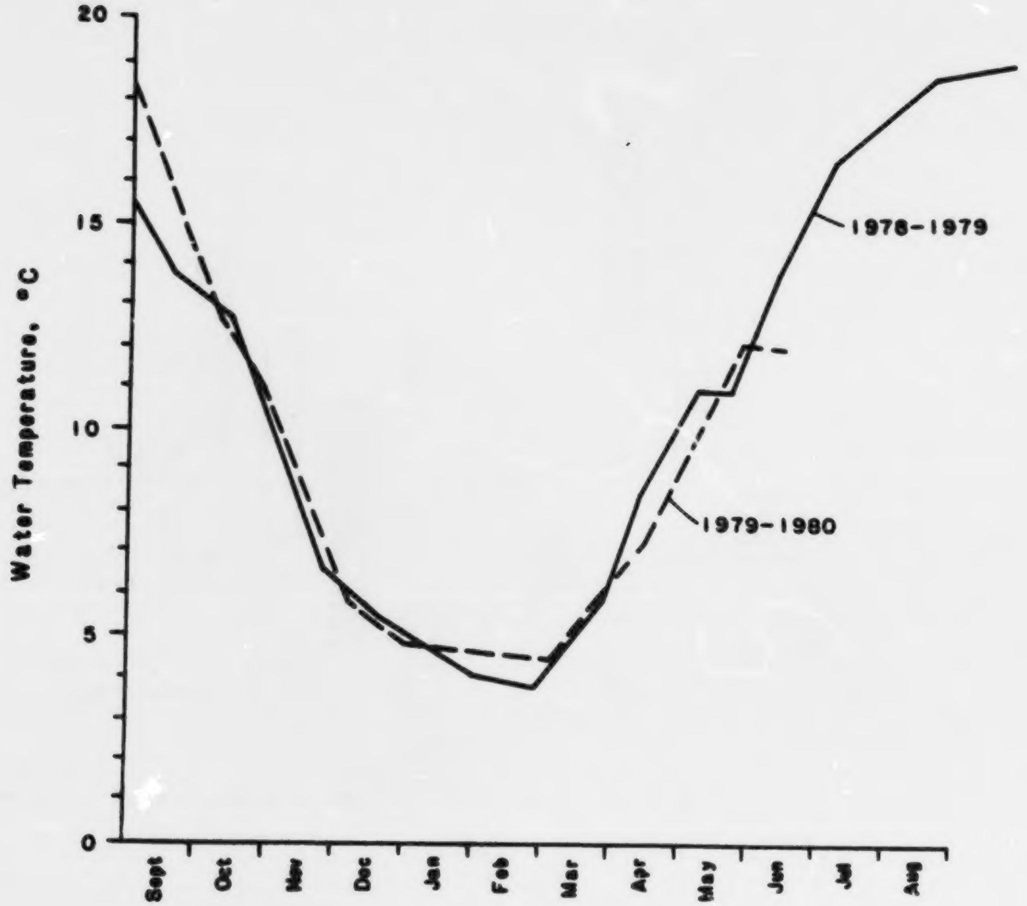
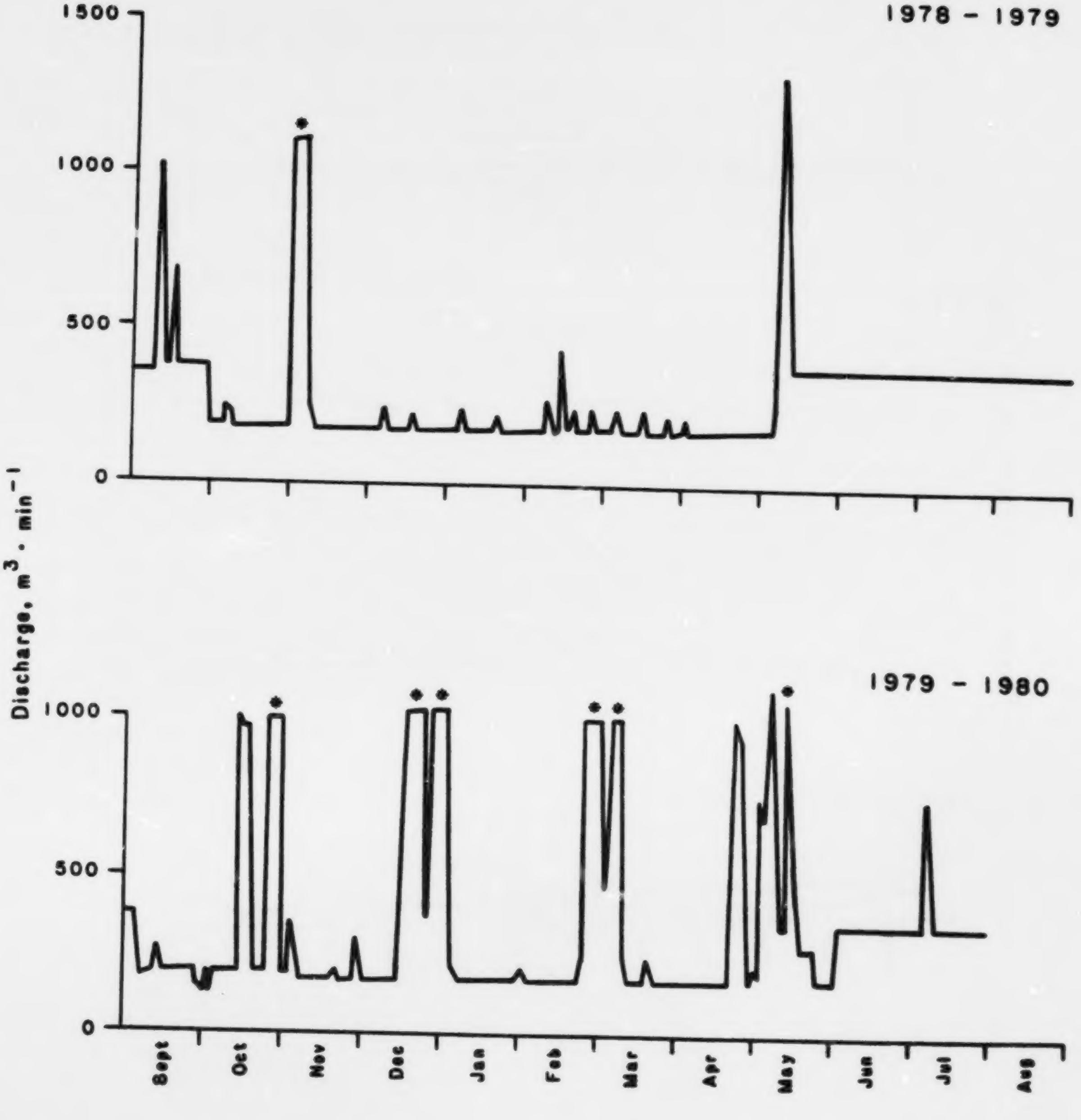


Fig. 17 Puntledge River

Water Discharge (recorded at Site 3)



(* – flood spill of 2000–7000 $m^3 \cdot min^{-1}$)

Fig. 18 Puntledge River
Total Phosphate Concentrations

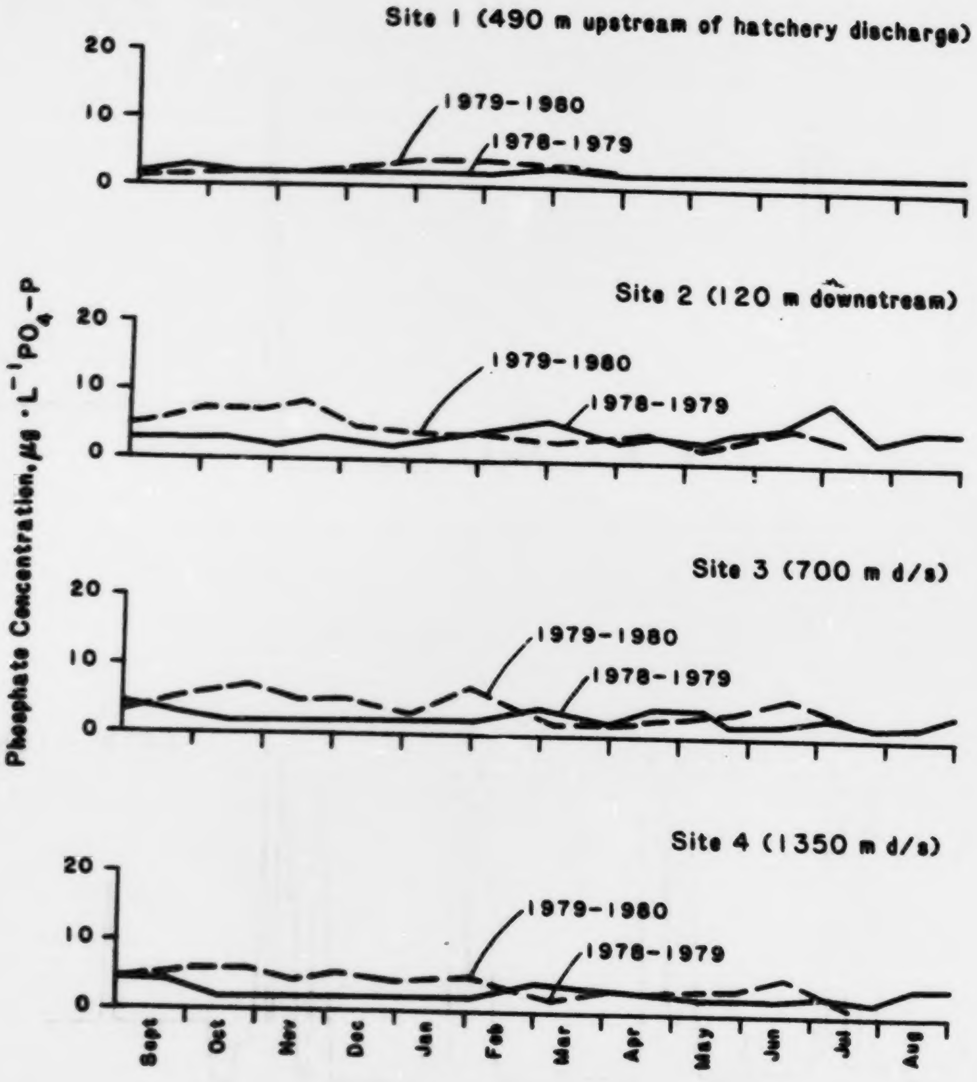


Fig. 19 Puntledge River

Total Ammonia Concentrations – Filtered Samples

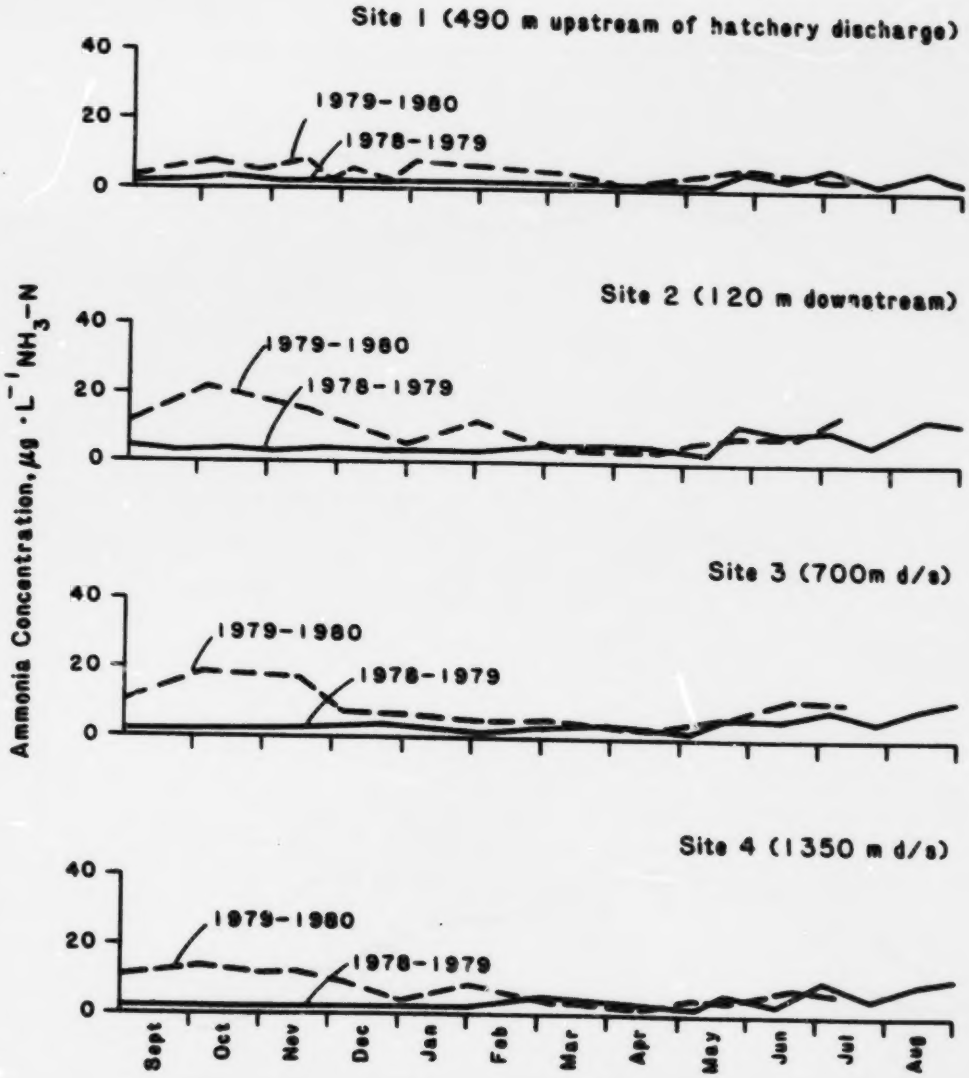


Fig. 20 Puntledge River

Total Nitrate Concentrations – Filtered Samples

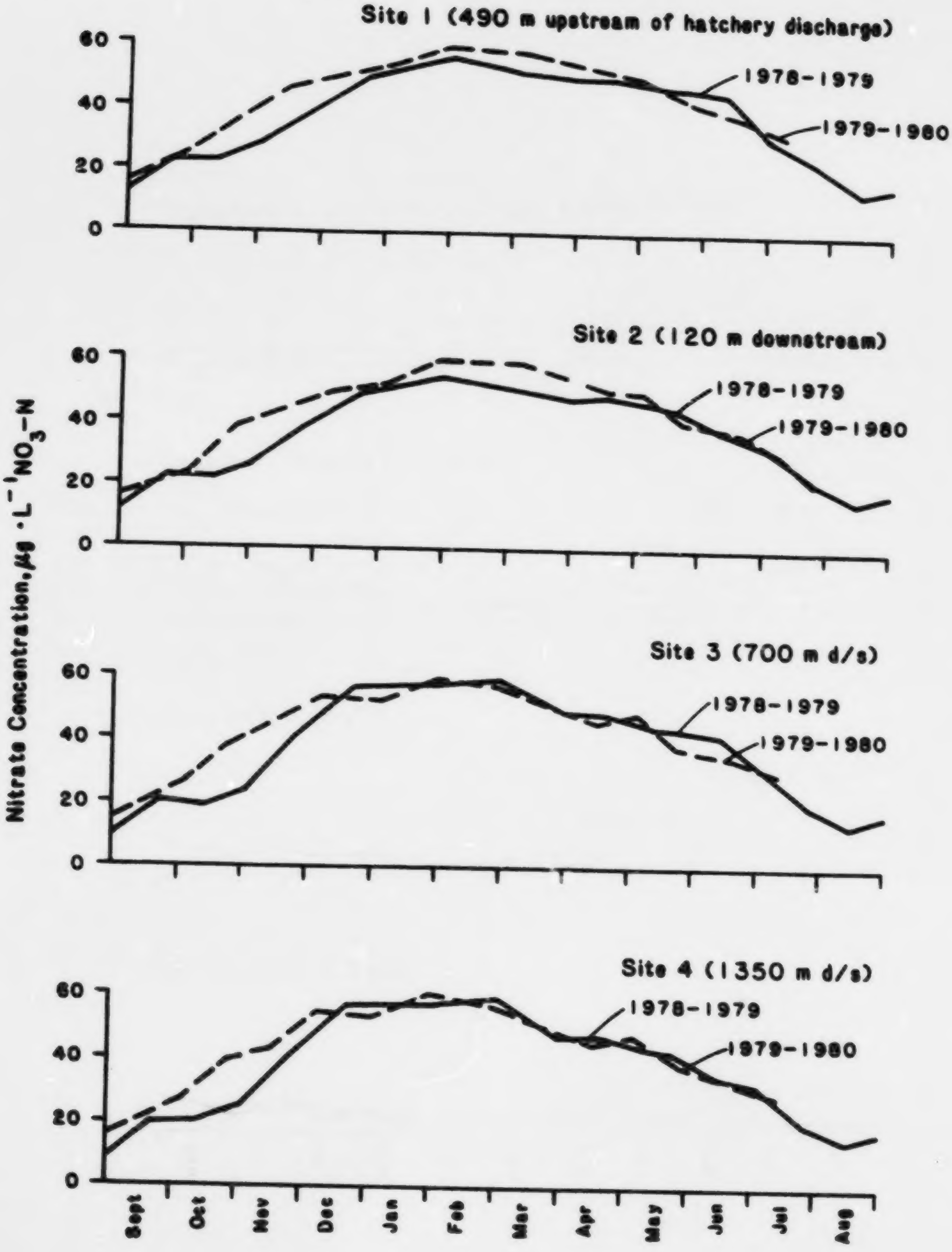


Fig. 21 Puntledge River
Fish Rearing Information

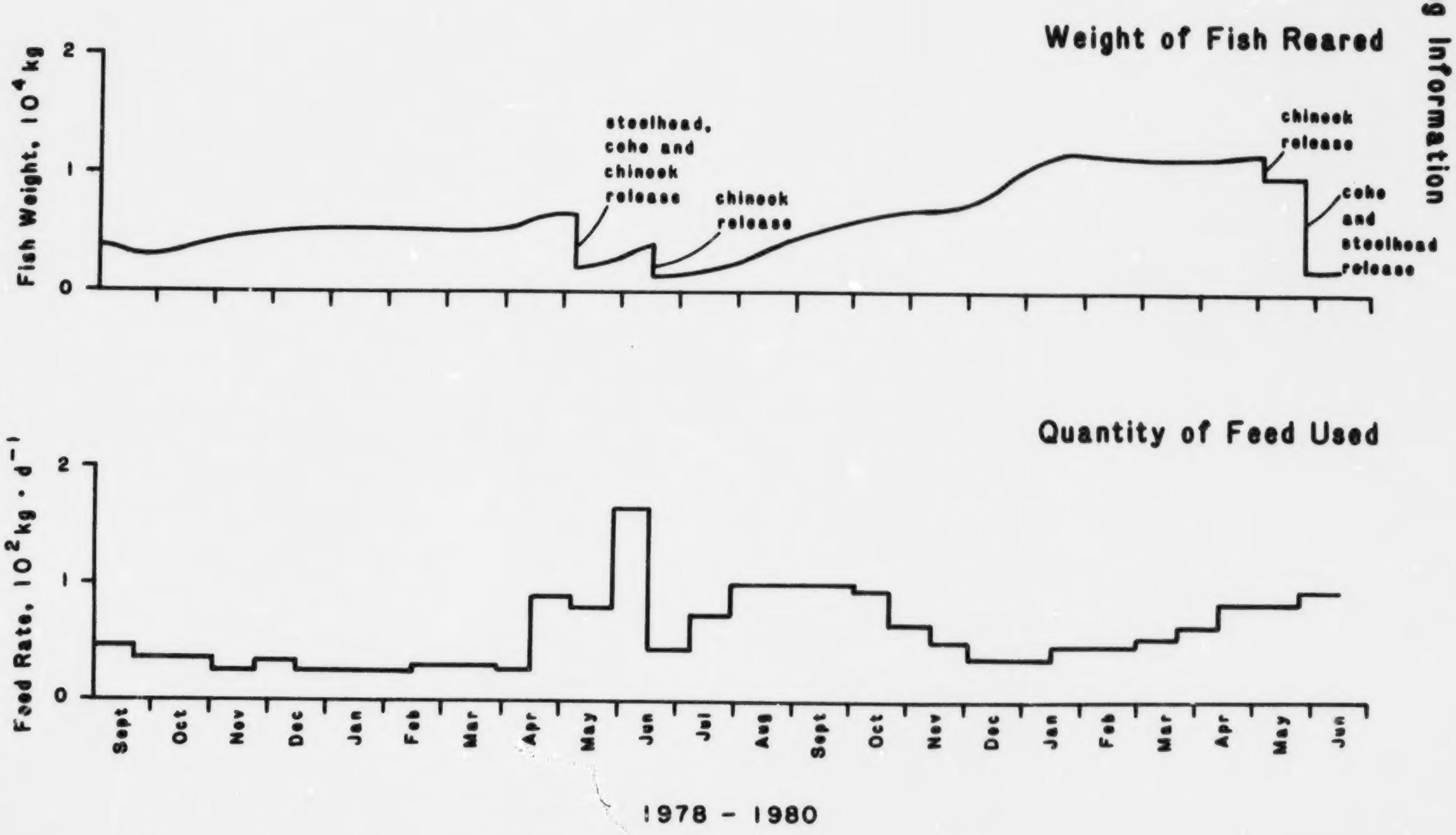
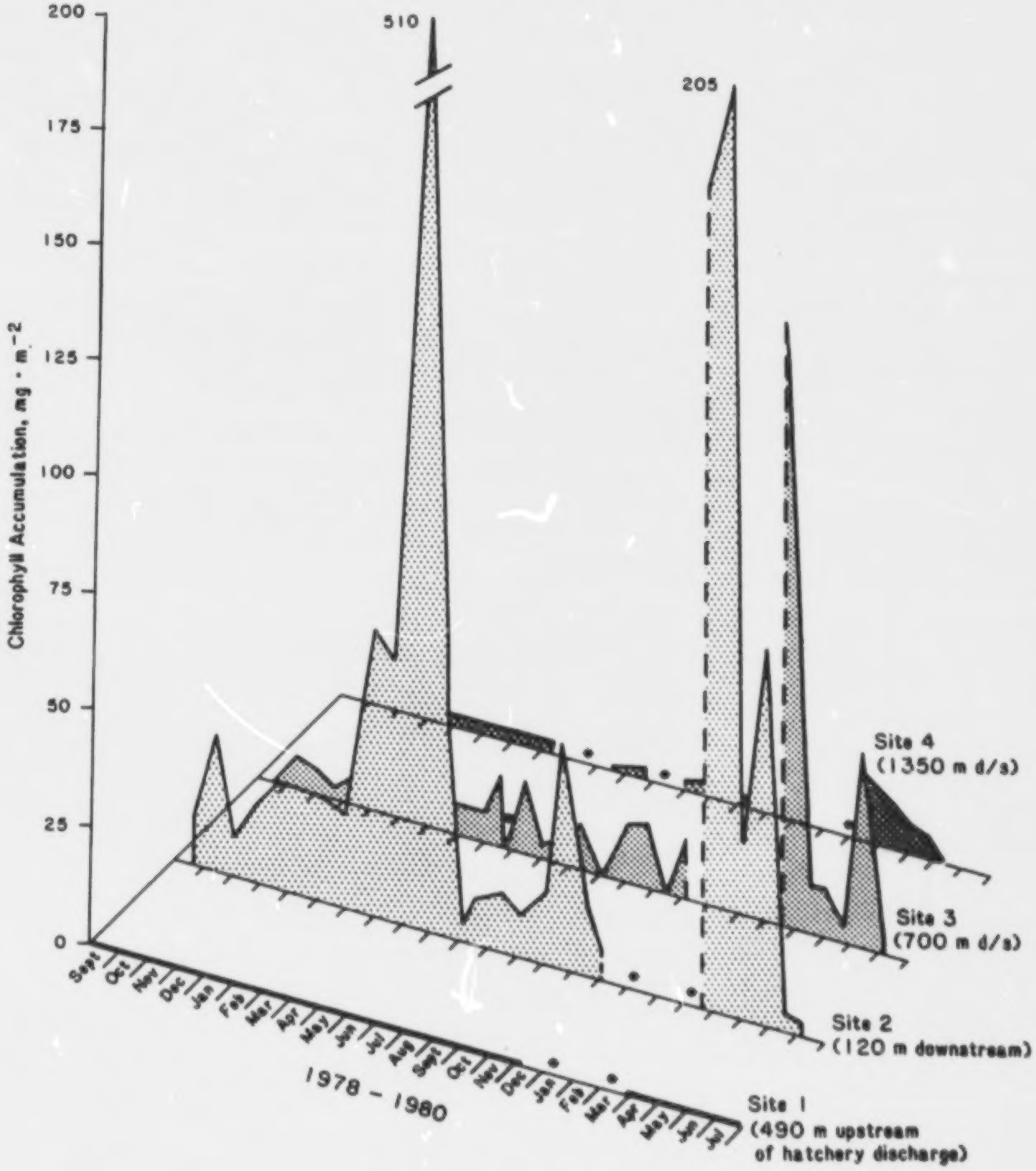


Fig. 21 Puntledge River
Fish Rearing Information

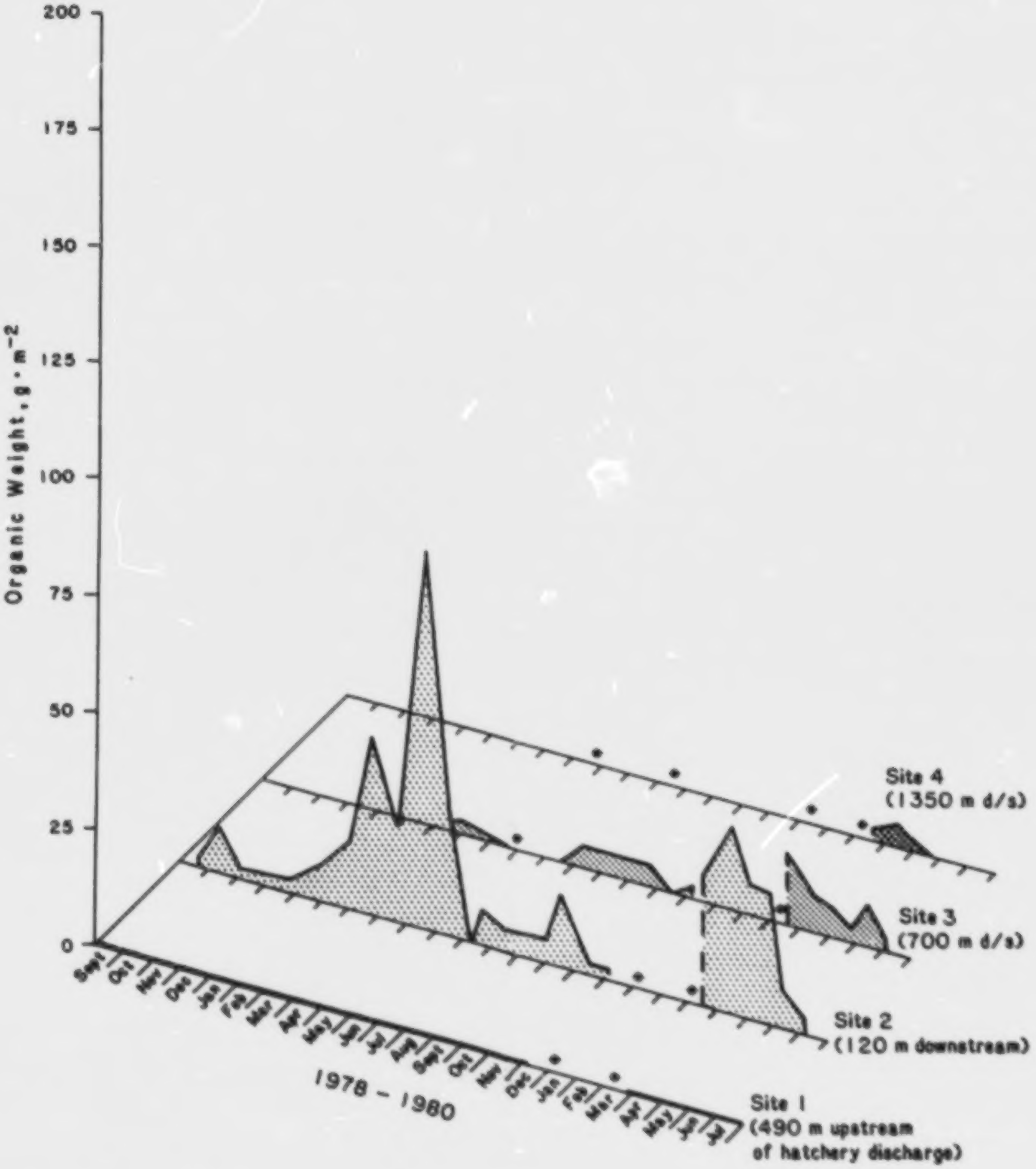
Fig. 22(a) Puntledge River – Pool Sites
Periphyton Chlorophyll a



(• – flood losses)

Fig. 22(a) cont. Puntledge River – Pool Sites

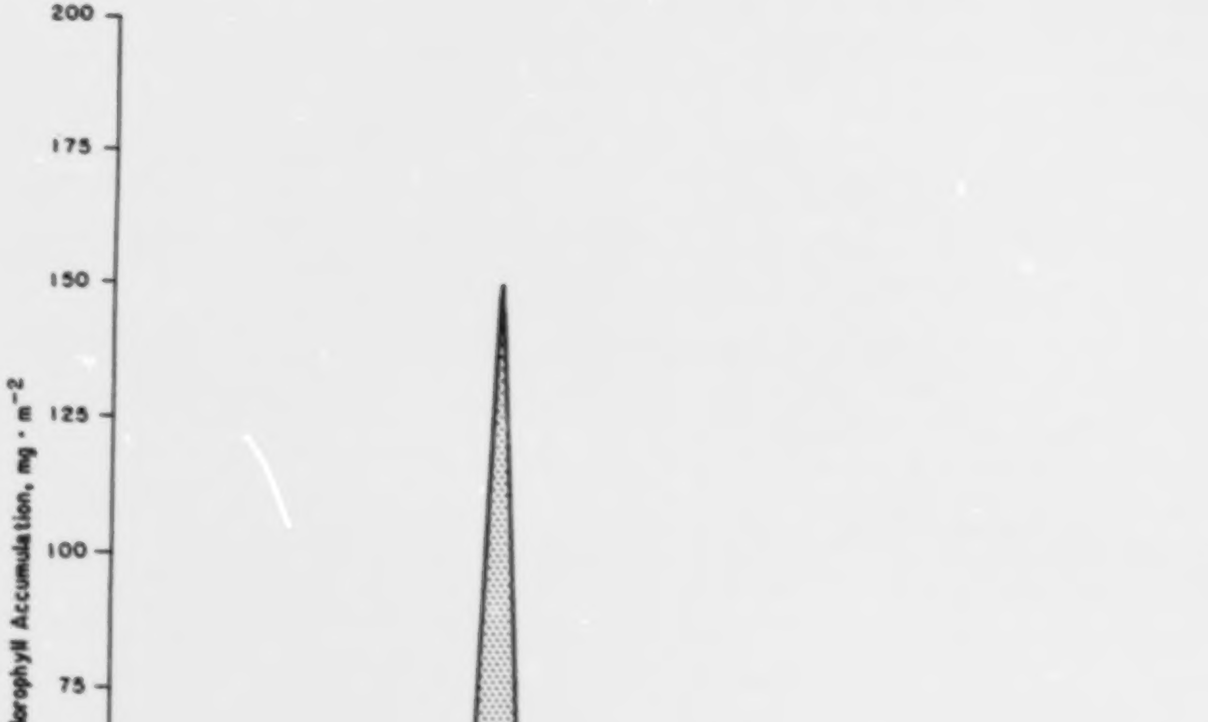
Periphyton Organic Weight



(* – flood losses)

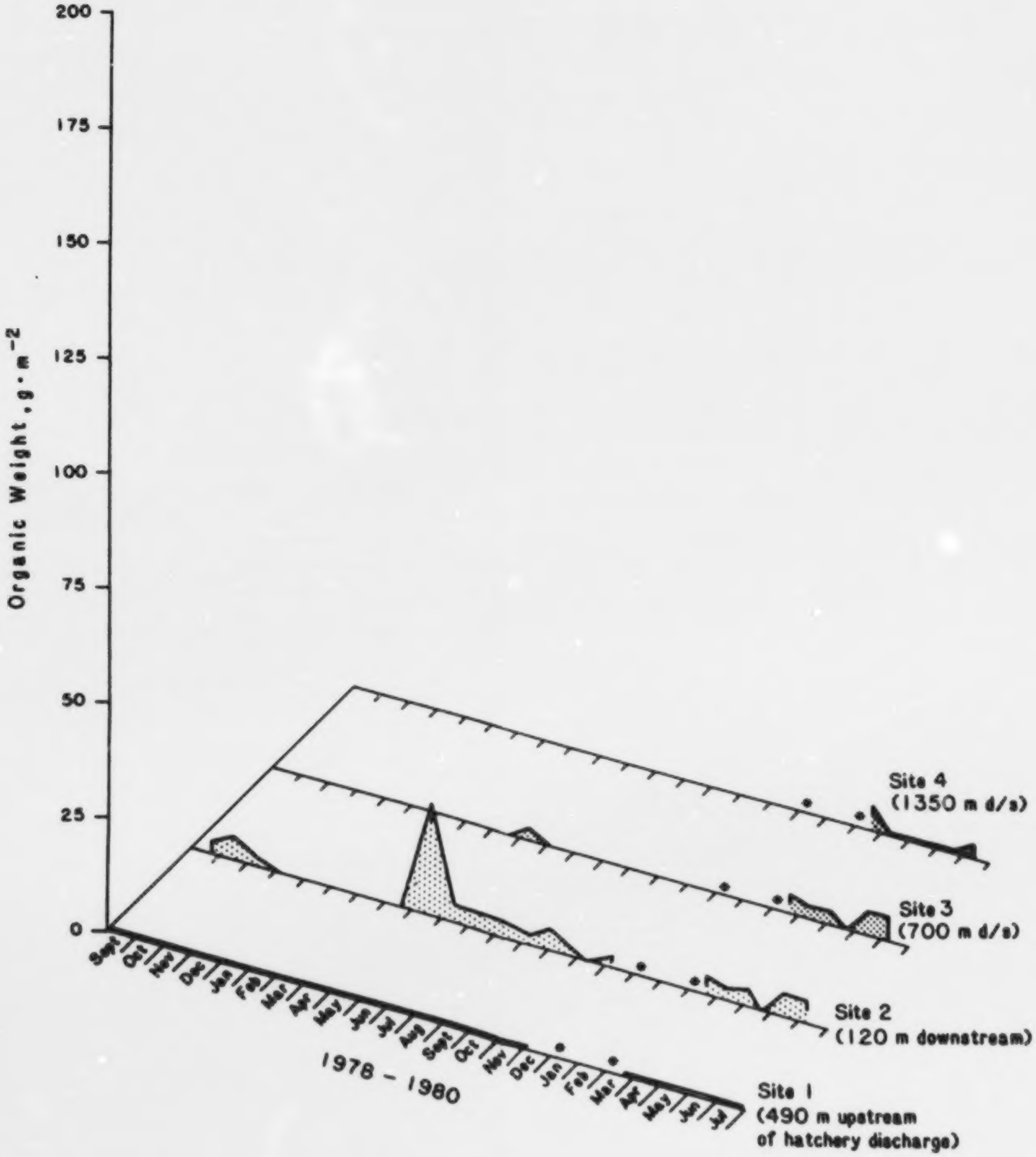
Fig. 2.2(b) Puntledge River – Riffle Sites

Periphyton Chlorophyll a



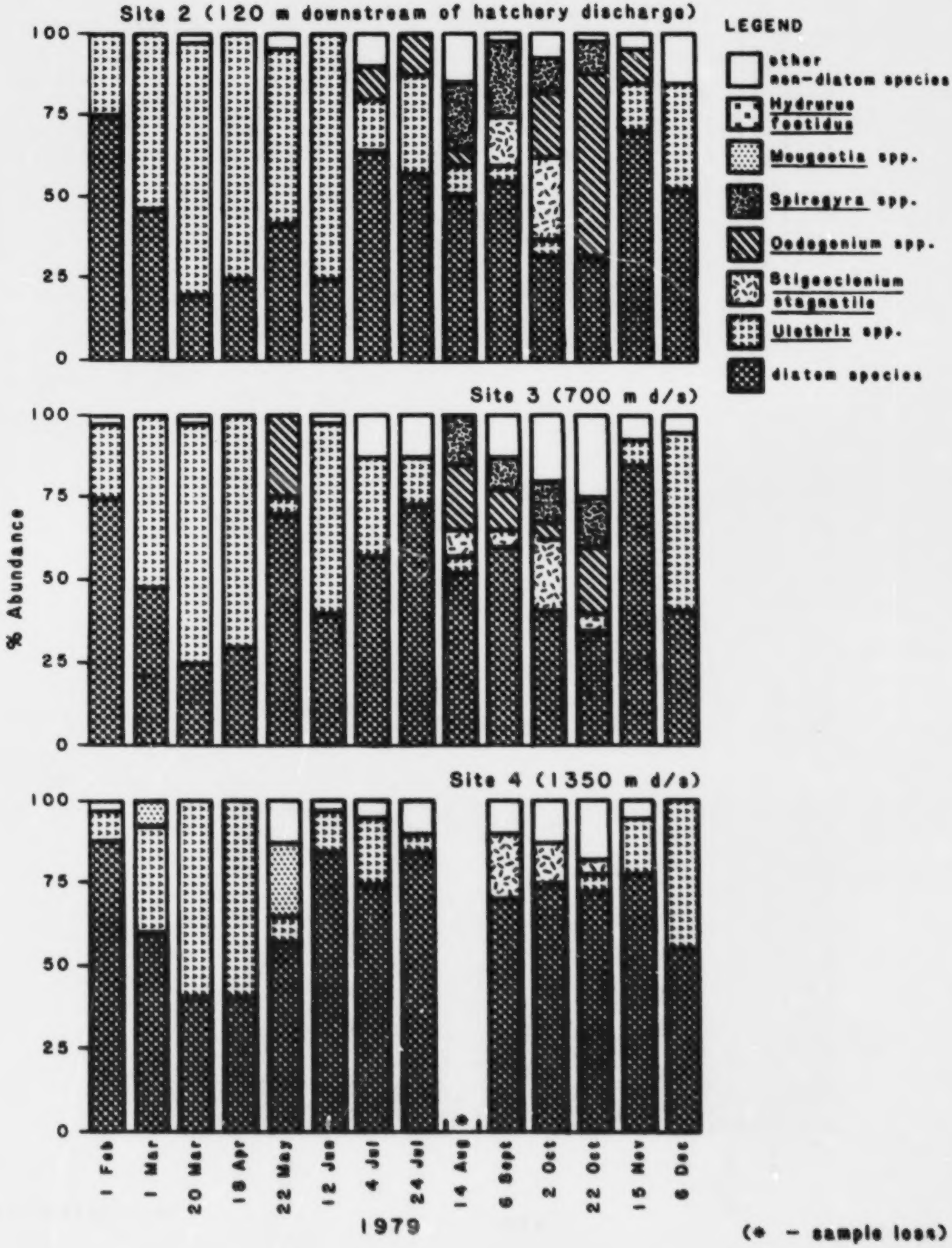
(* – flood losses)

Fig. 22(b) cont. Puntledge River – Riffle Sites
Periphyton Organic Weight



(* – flood losses)

Fig. 23(a) Puntledge River – Pool Sites
Periphyton Species Composition, % Abundance



(* – sample loss)

Fig. 23(b) Puntledge River - Riffle Sites
Periphyton Species Composition, % Abundance

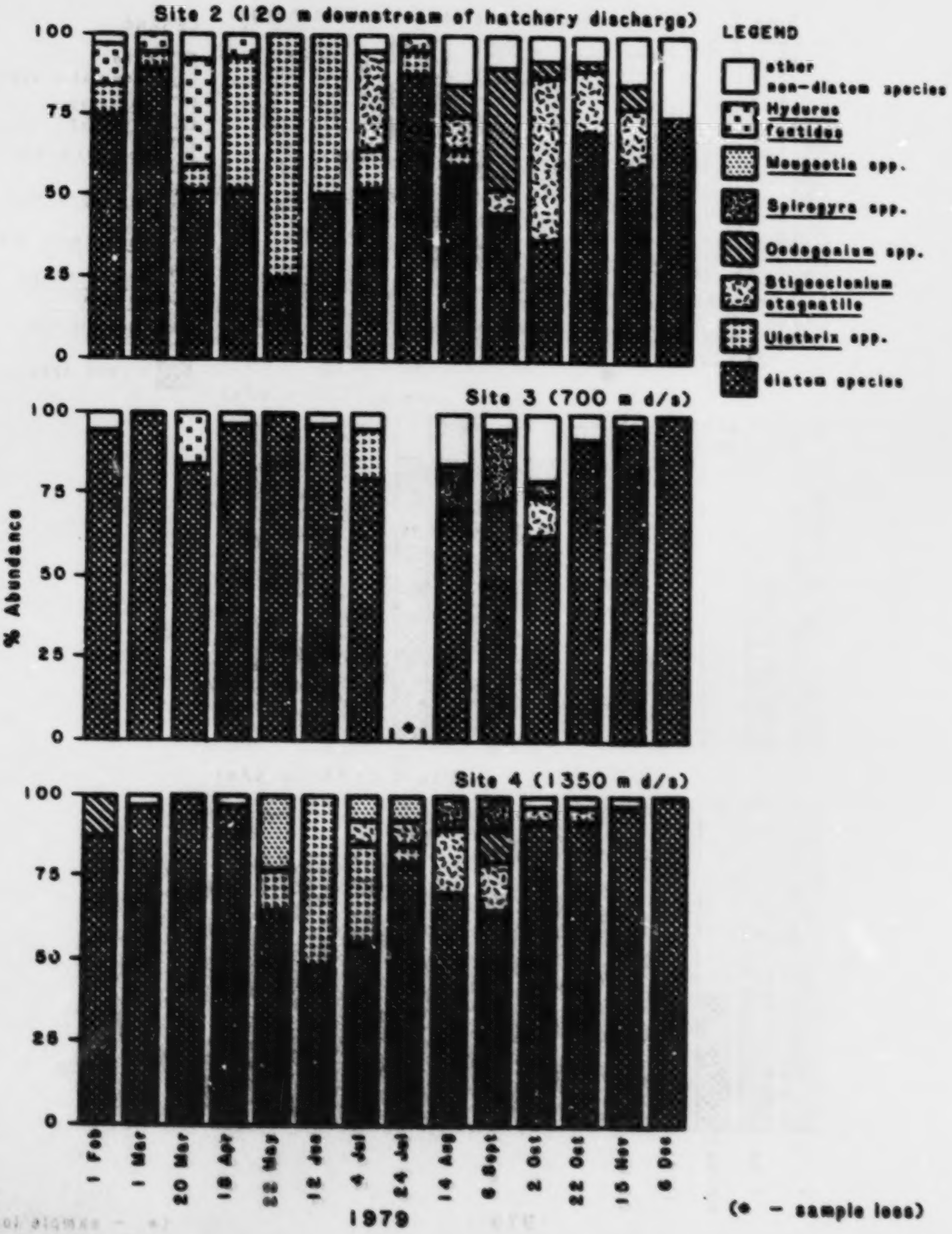
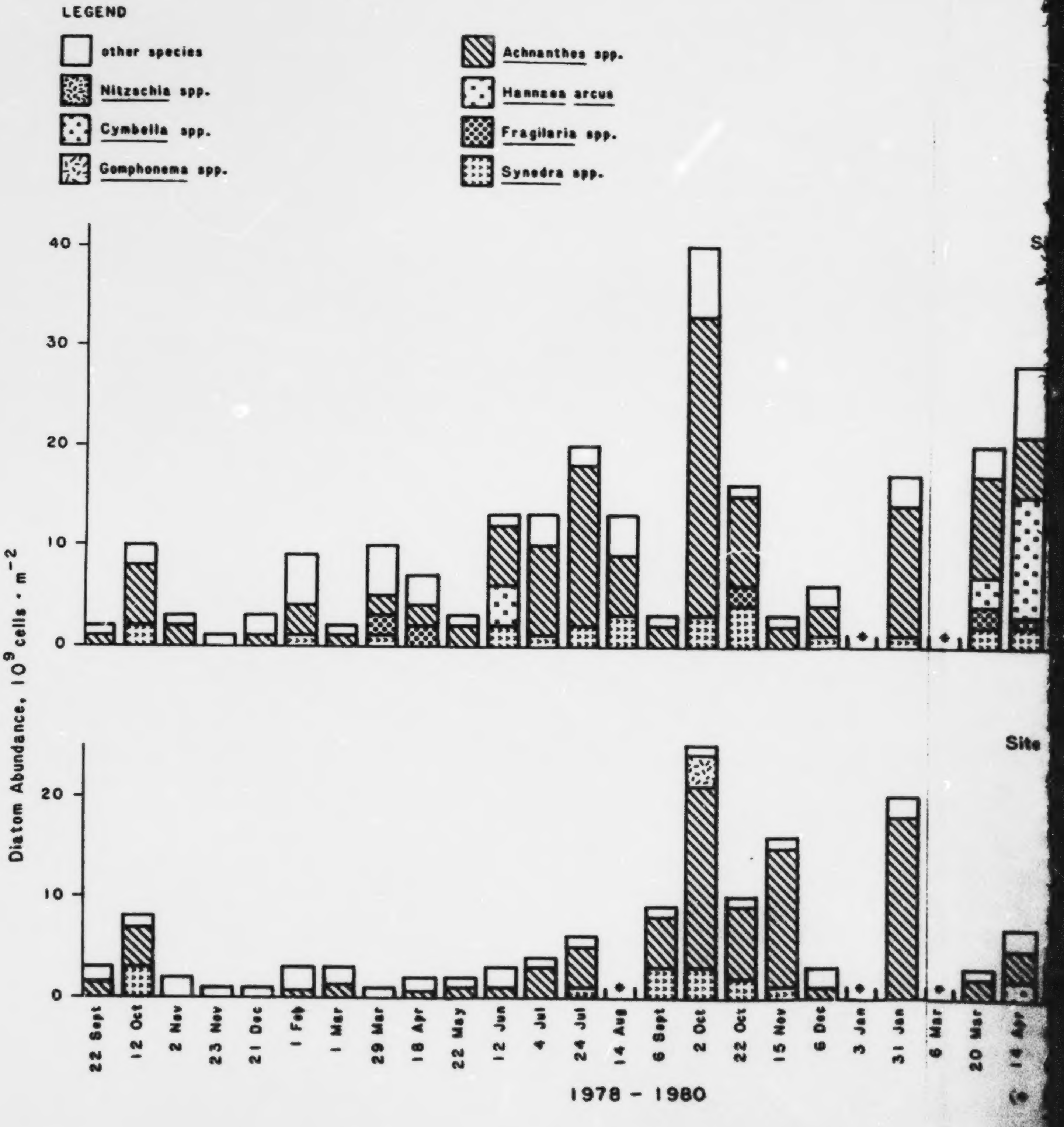
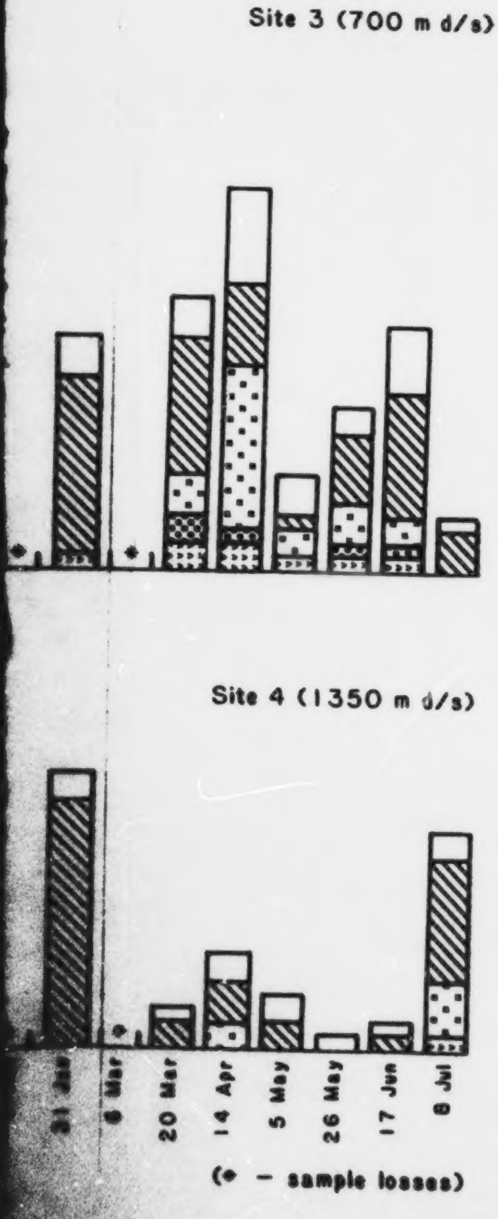


Fig. 24(a) cont. Puntledge River – Pool Sites
Diatom Assemblage Size and Composition



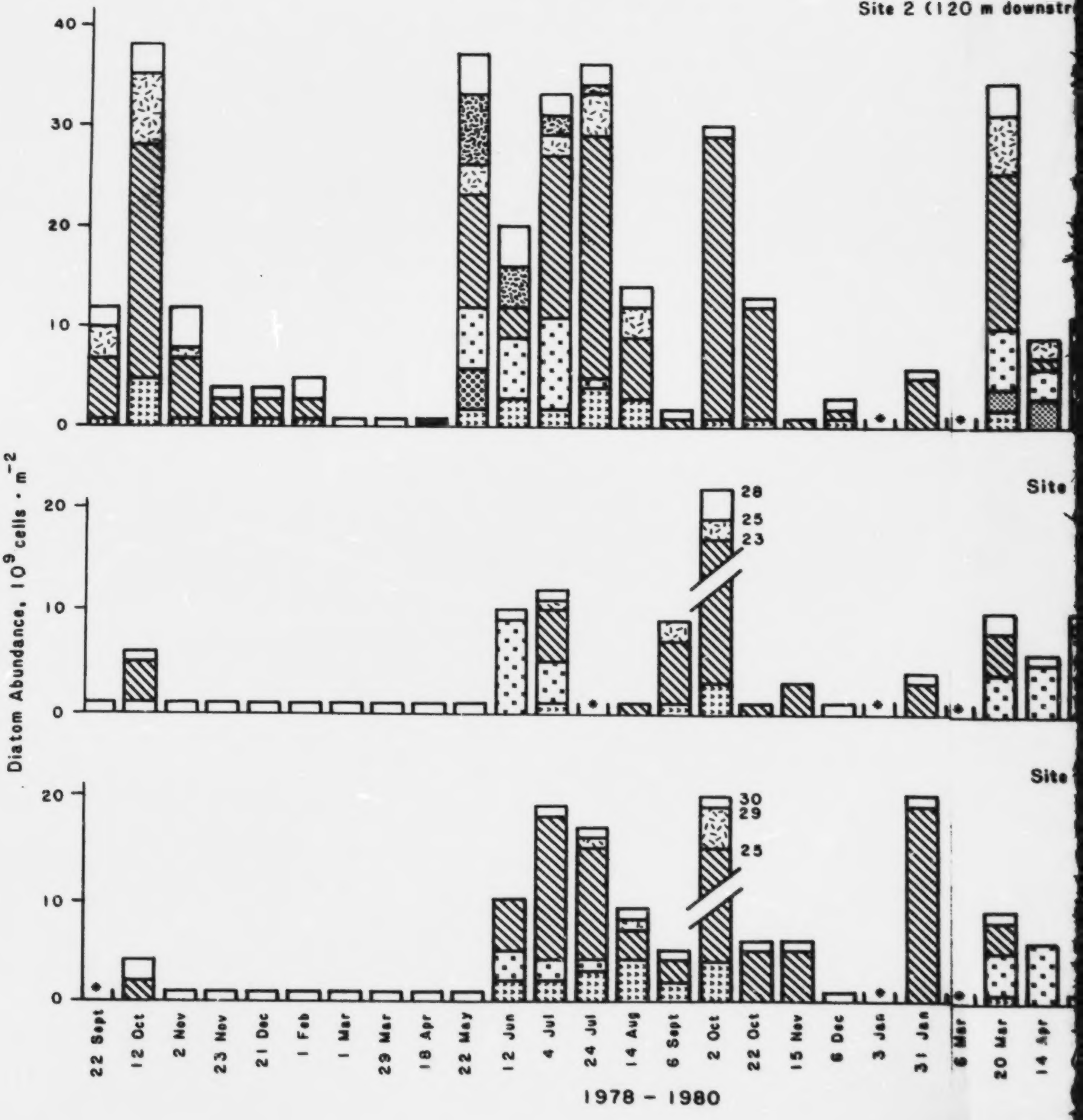


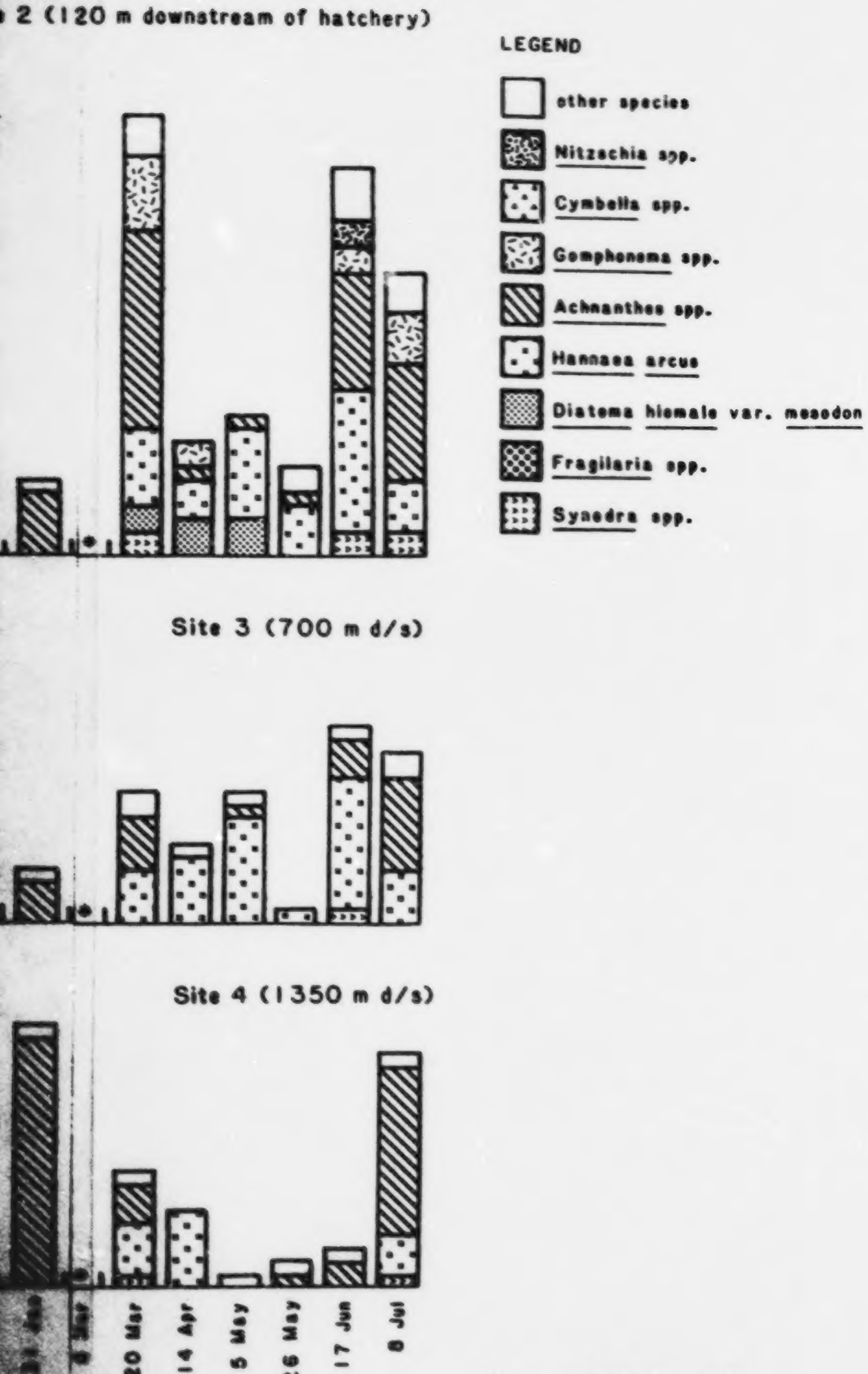
Site 3 (700 m d/s)

Site 4 (1350 m d/s)

(* – sample losses)

Fig. 24(b) Puntledge River – Riffle Sites
Diatom Assemblage Size and Composition





(* - sample losses)

Fig. 25 Puntledge River
Benthic Invertebrate Abundance

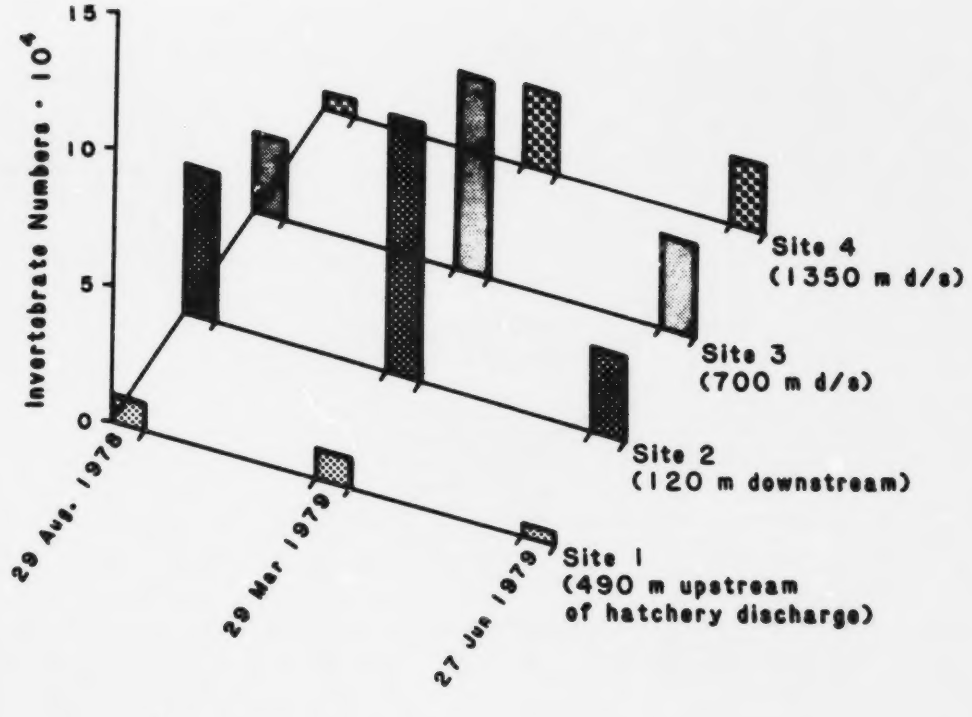


Fig. 26 Big Qualicum River
Water Temperatures

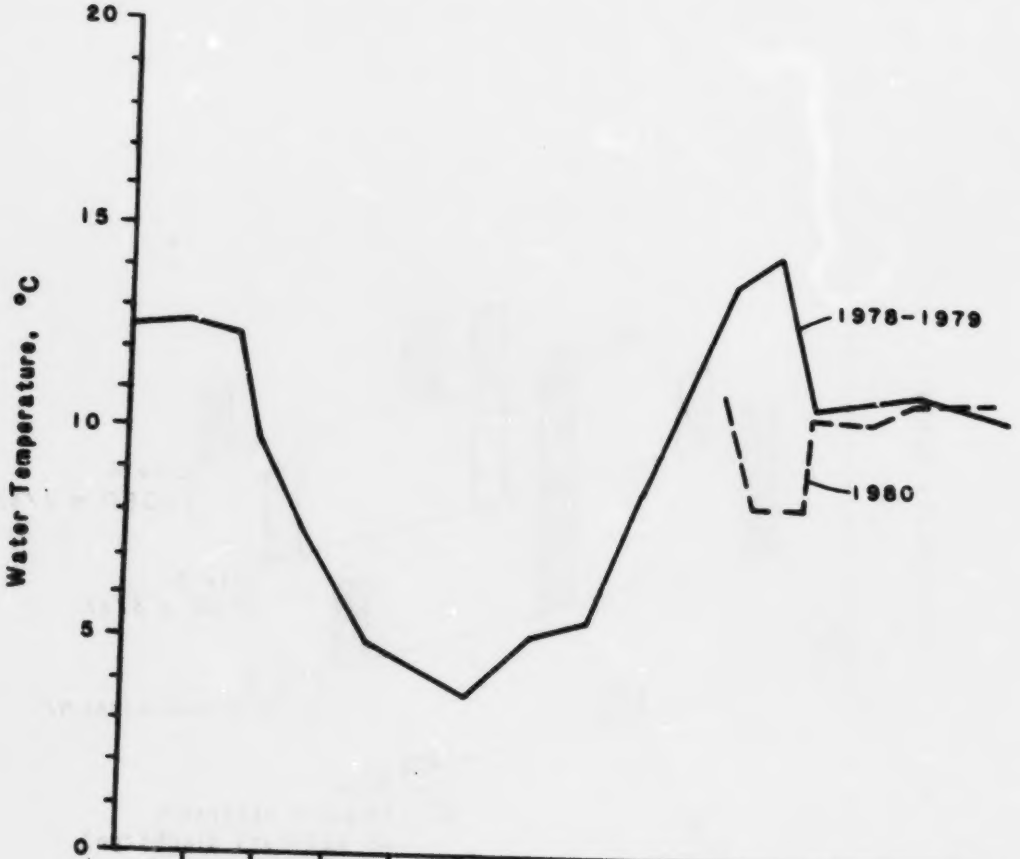


Fig. 27 Big Qualicum River
Water Discharge (recorded at Horne Lake)

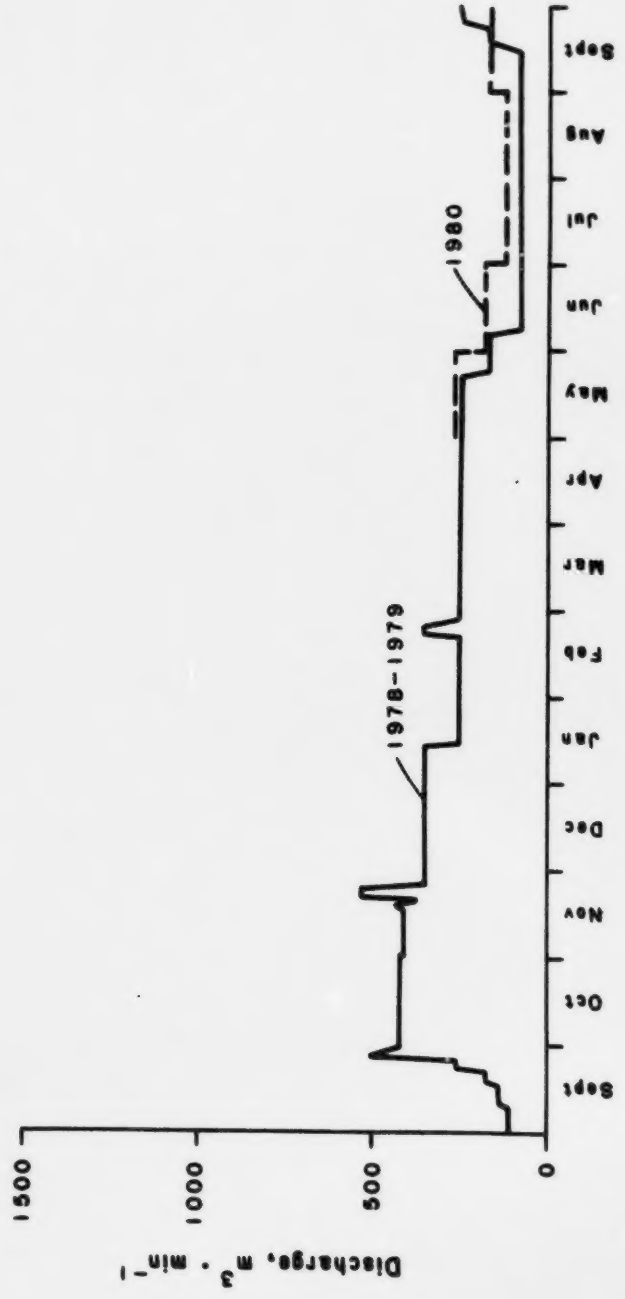


Fig. 28 Big Qualicum River

Total Phosphate Concentrations

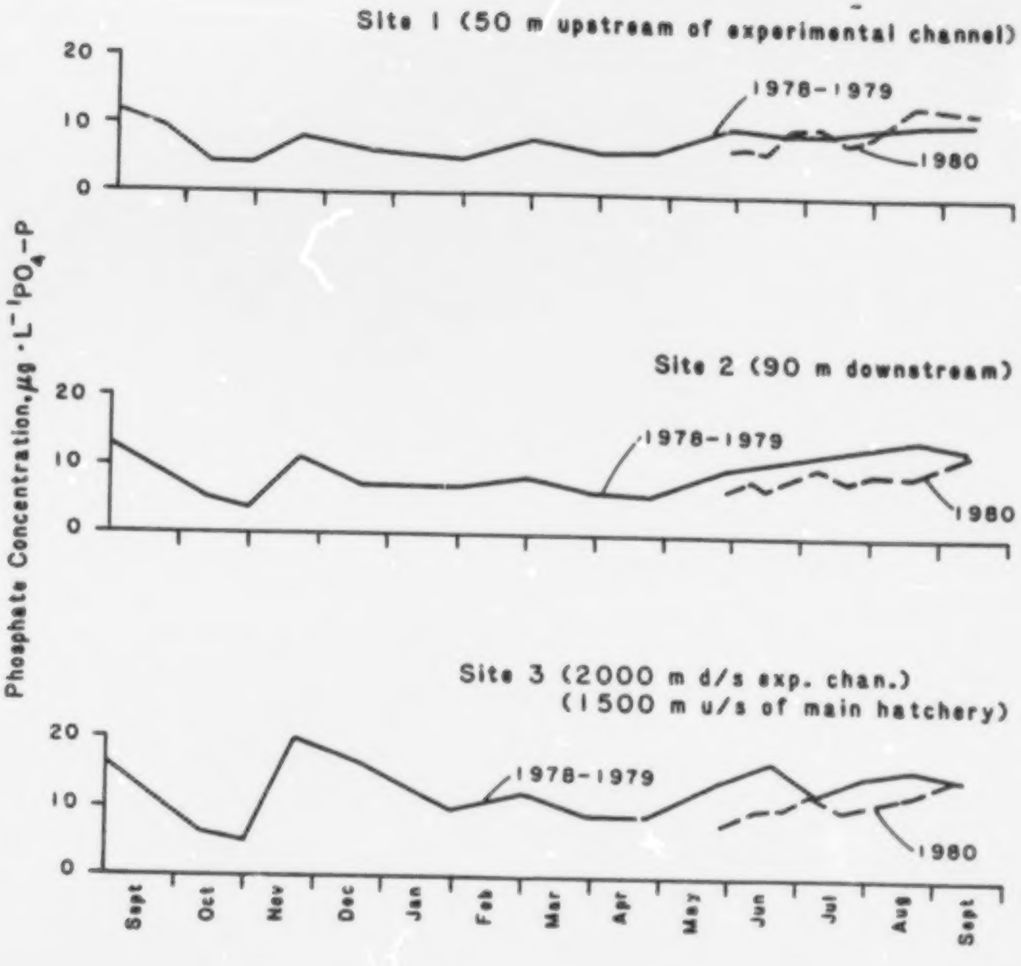


Fig. 28 cont. Big Qualicum River
Total Phosphate Concentrations

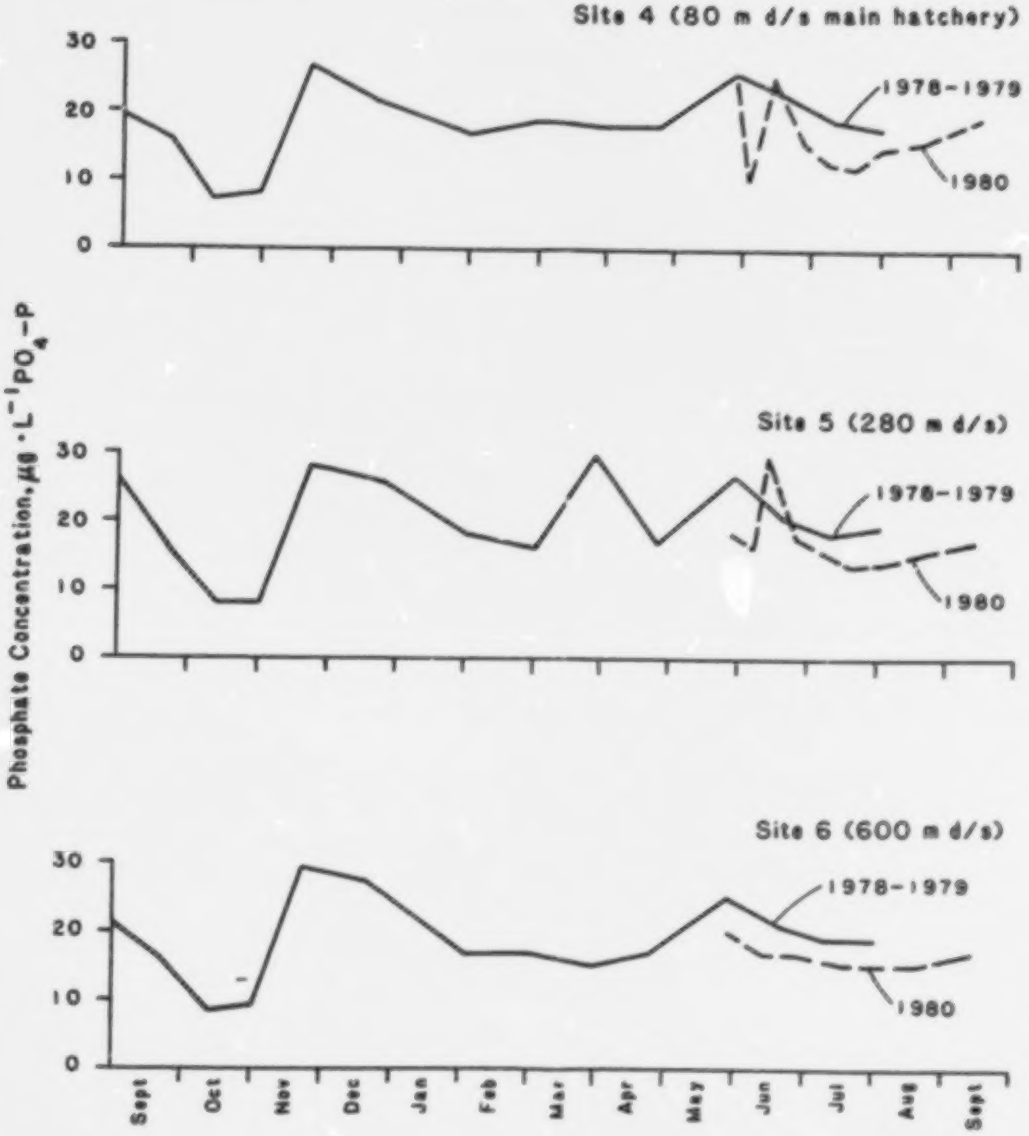
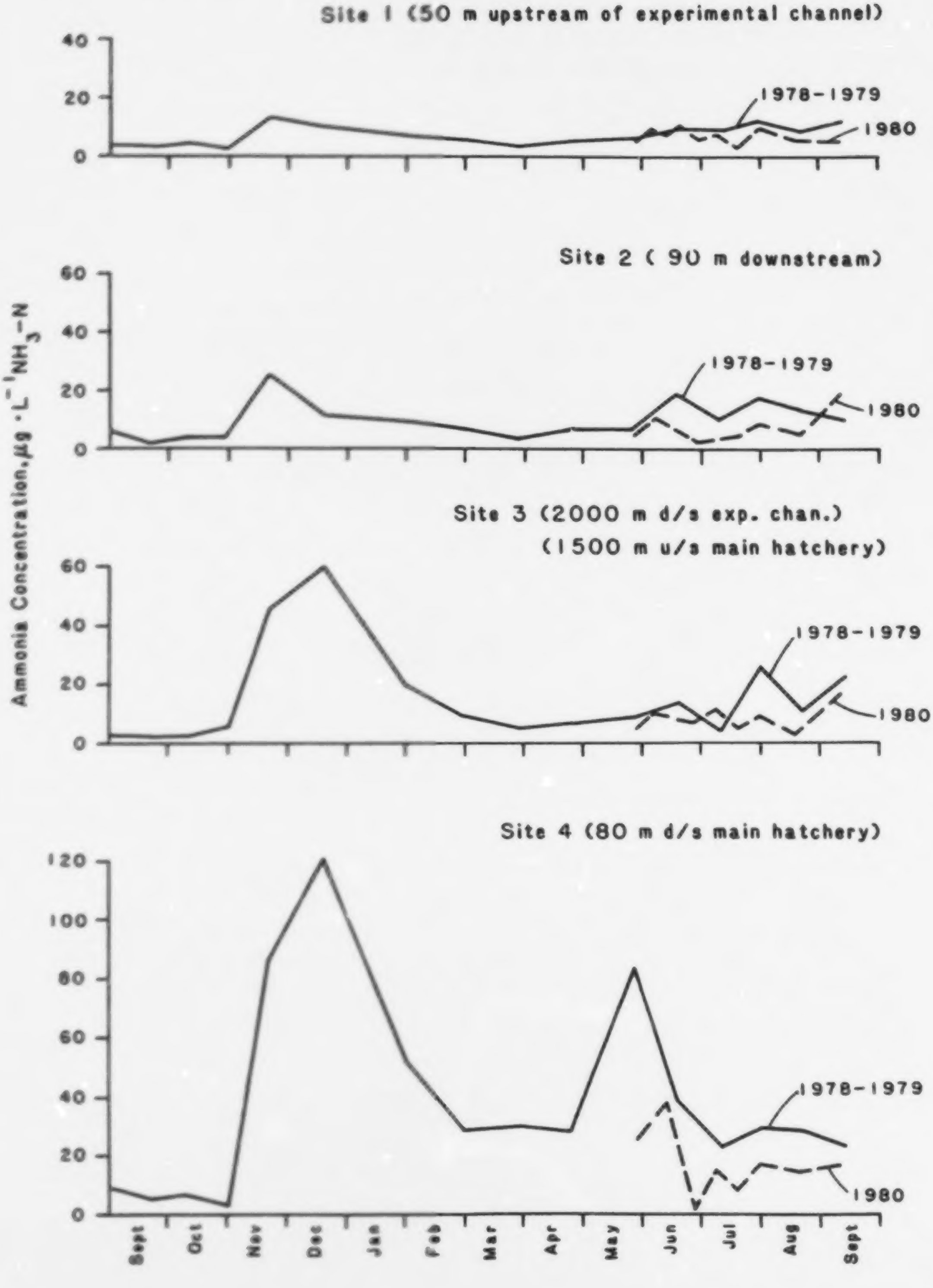


Fig. 29 Big Qualicum River

Total Ammonia Concentrations – Filtered Samples



Site 1 (50 m upstream of experimental channel)

Site 2 (90 m downstream)

Site 3 (2000 m d/s exp. chan.)
(1500 m u/s main hatchery)

Site 4 (80 m d/s main hatchery)

Fig. 29 cont. Big Qualicum River

Total Ammonia Concentrations – Filtered Samples

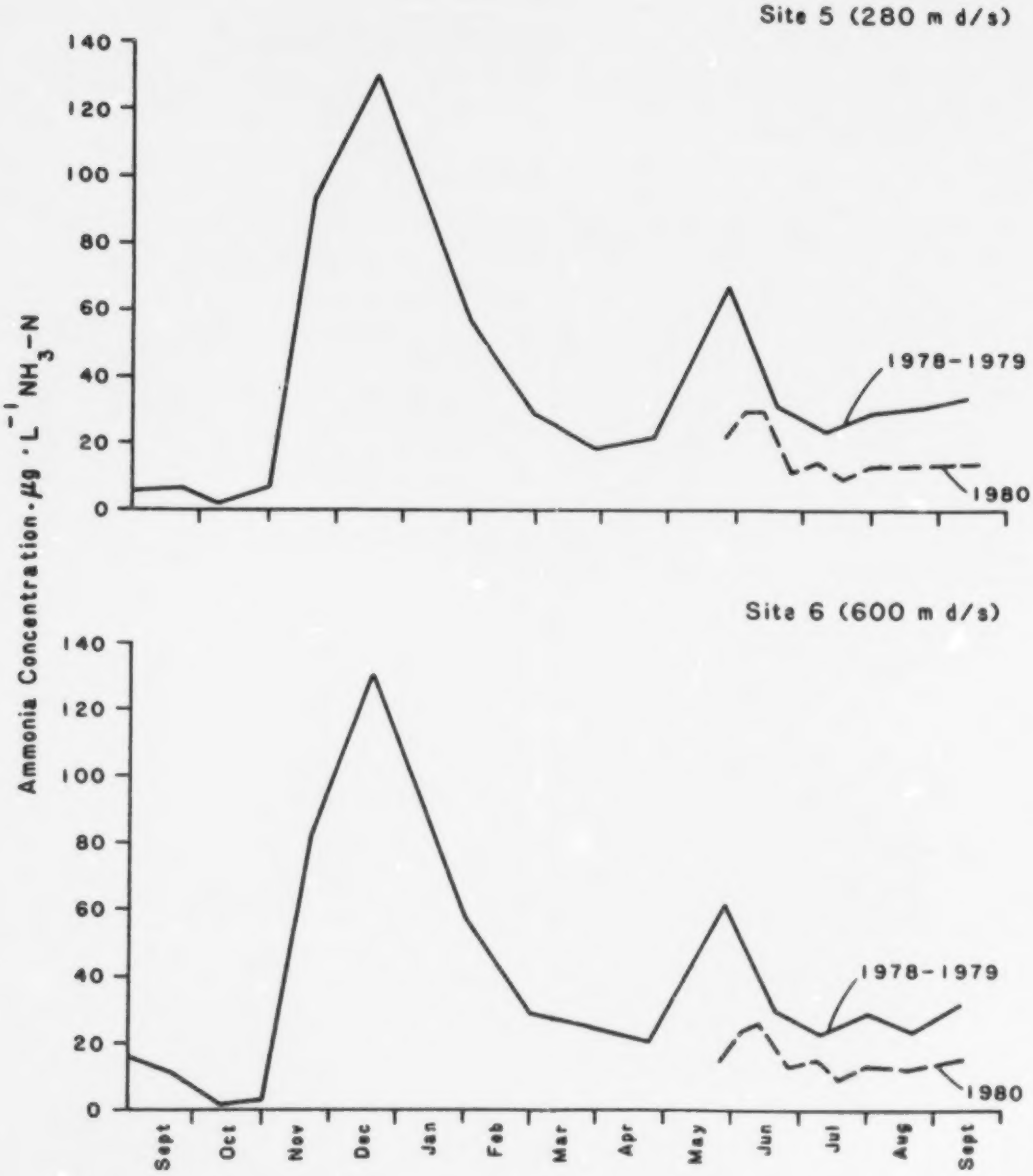


Fig. 30 Big Qualicum River
Total Nitrate Concentrations – Filtered Samples

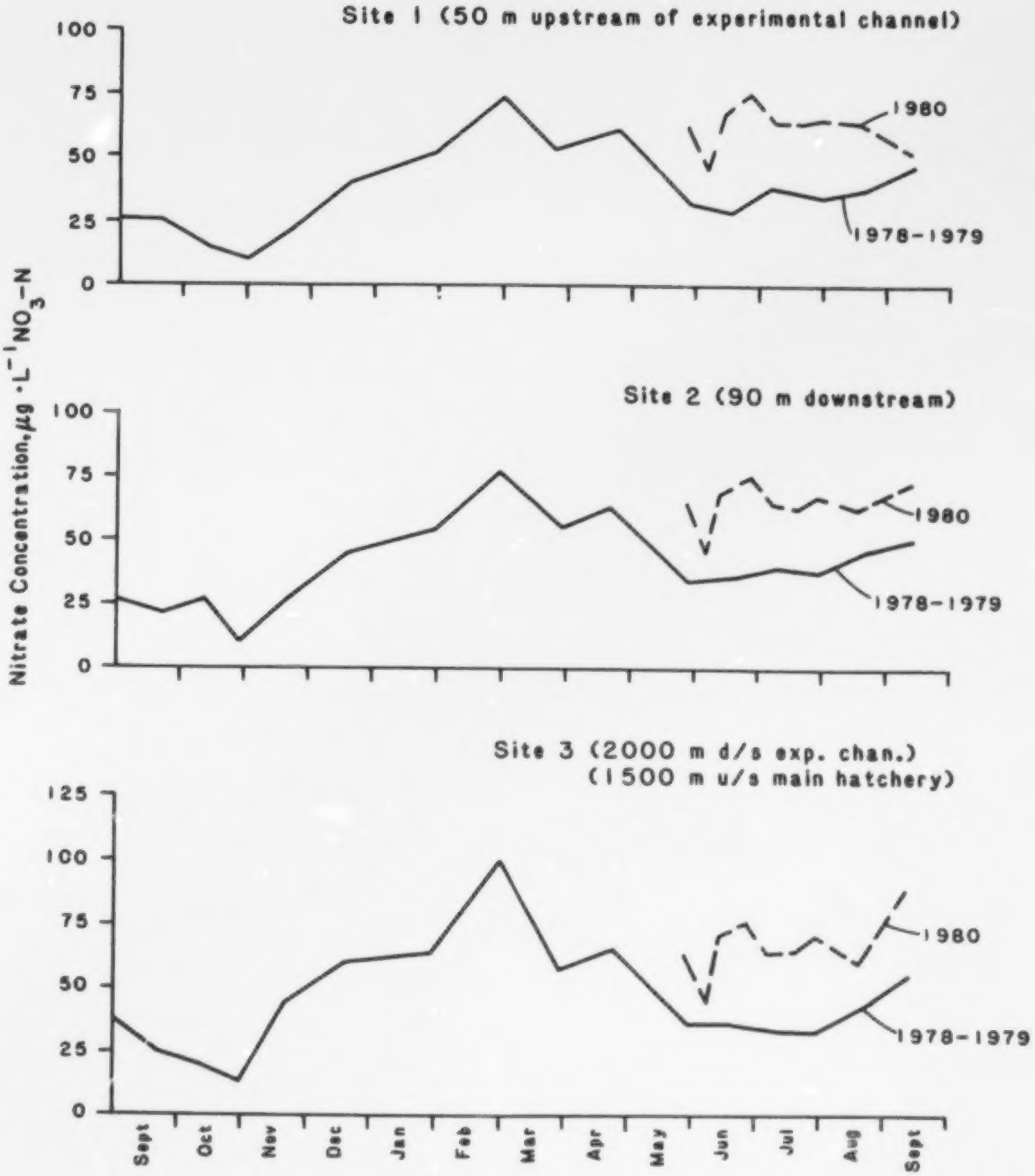


Fig. 30 cont. Big Qualicum River

Total Nitrate Concentrations – Filtered Samples

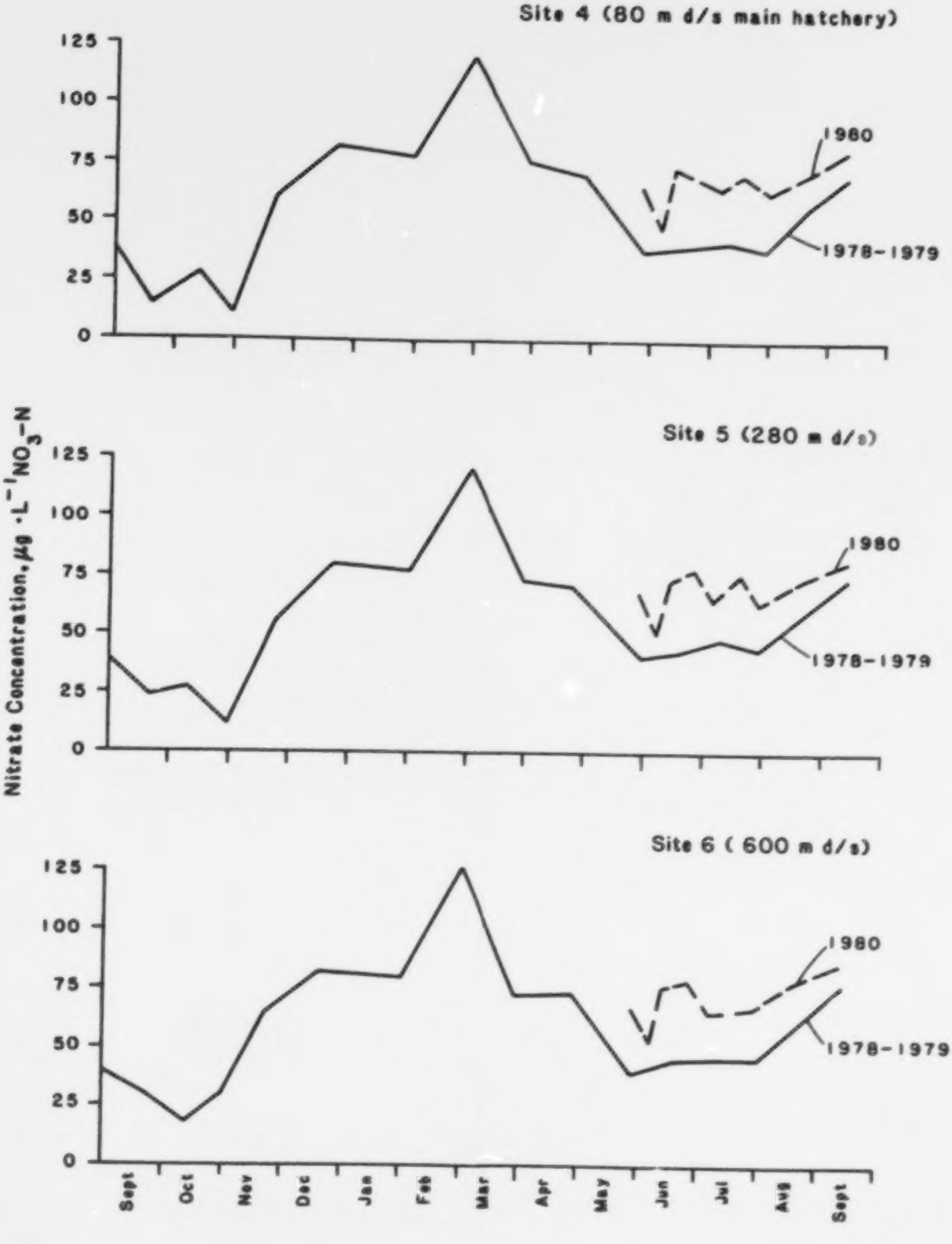


Fig. 31 Big Qualicum River
Fish Rearing Information

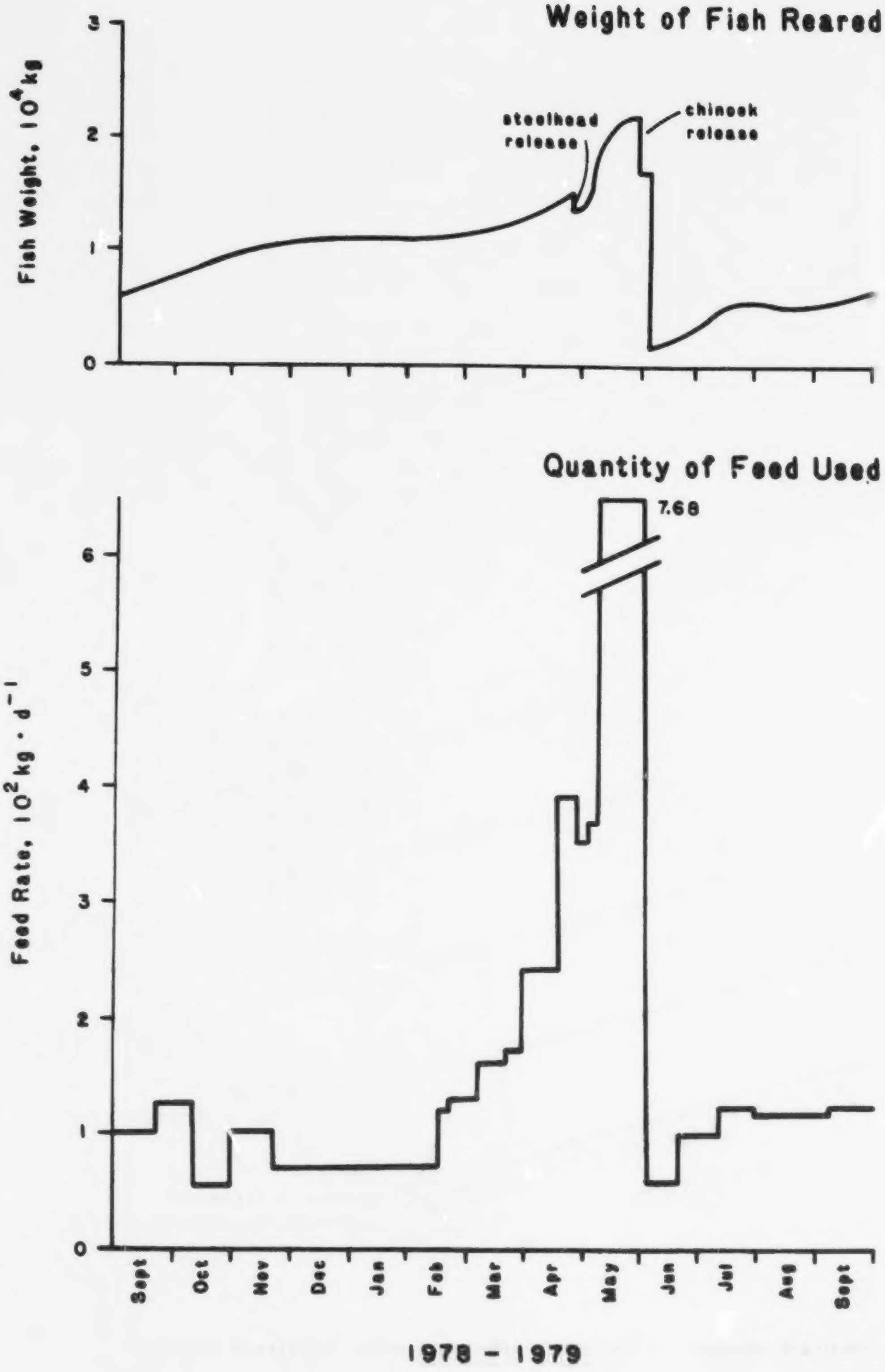
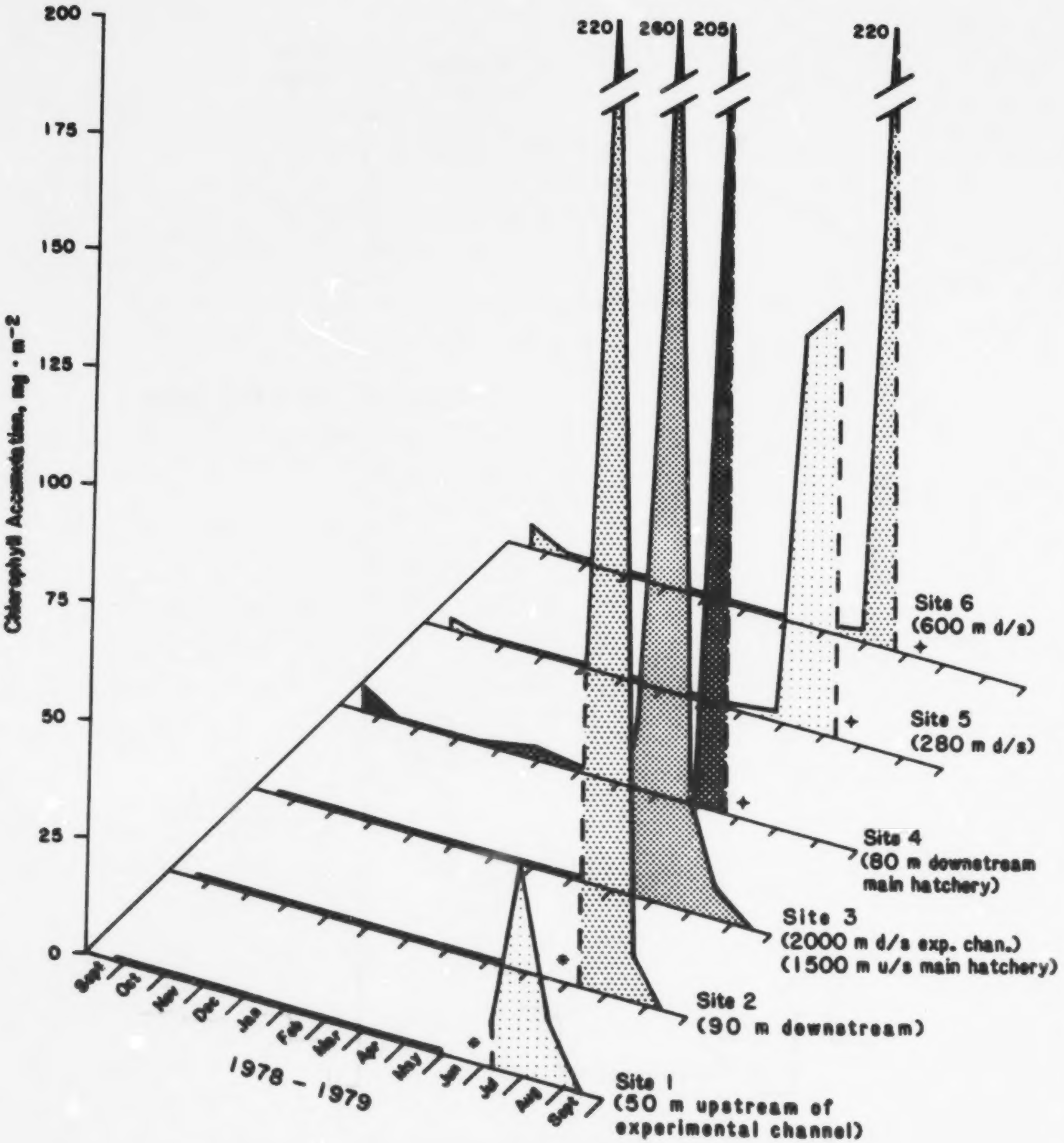


Fig. 32 Big Qualicum River – Riffle Sites

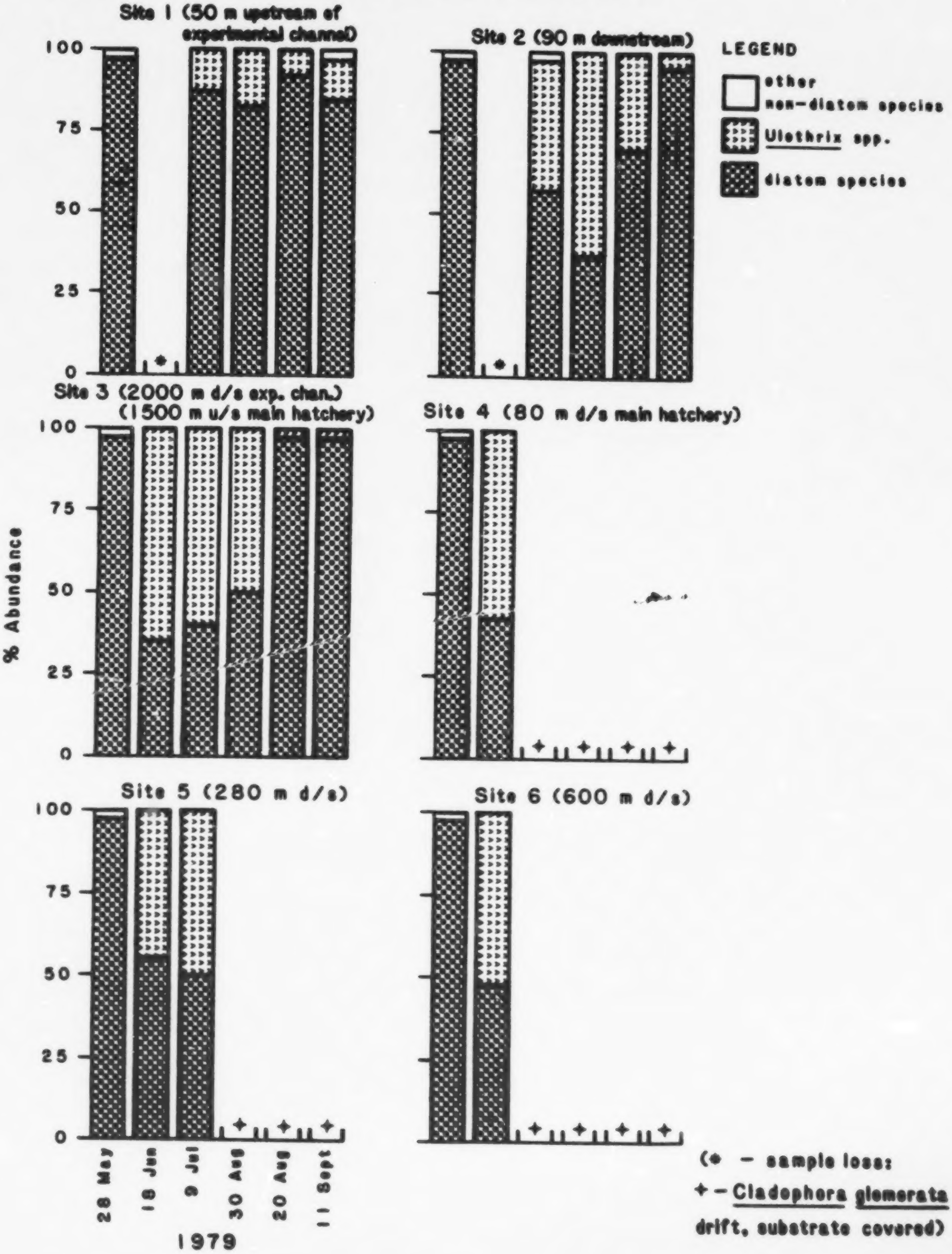
Periphyton Chlorophyll a



(● – low flow, substrate exposed: + – *Cladophora glomerata* drift, substrate covered)

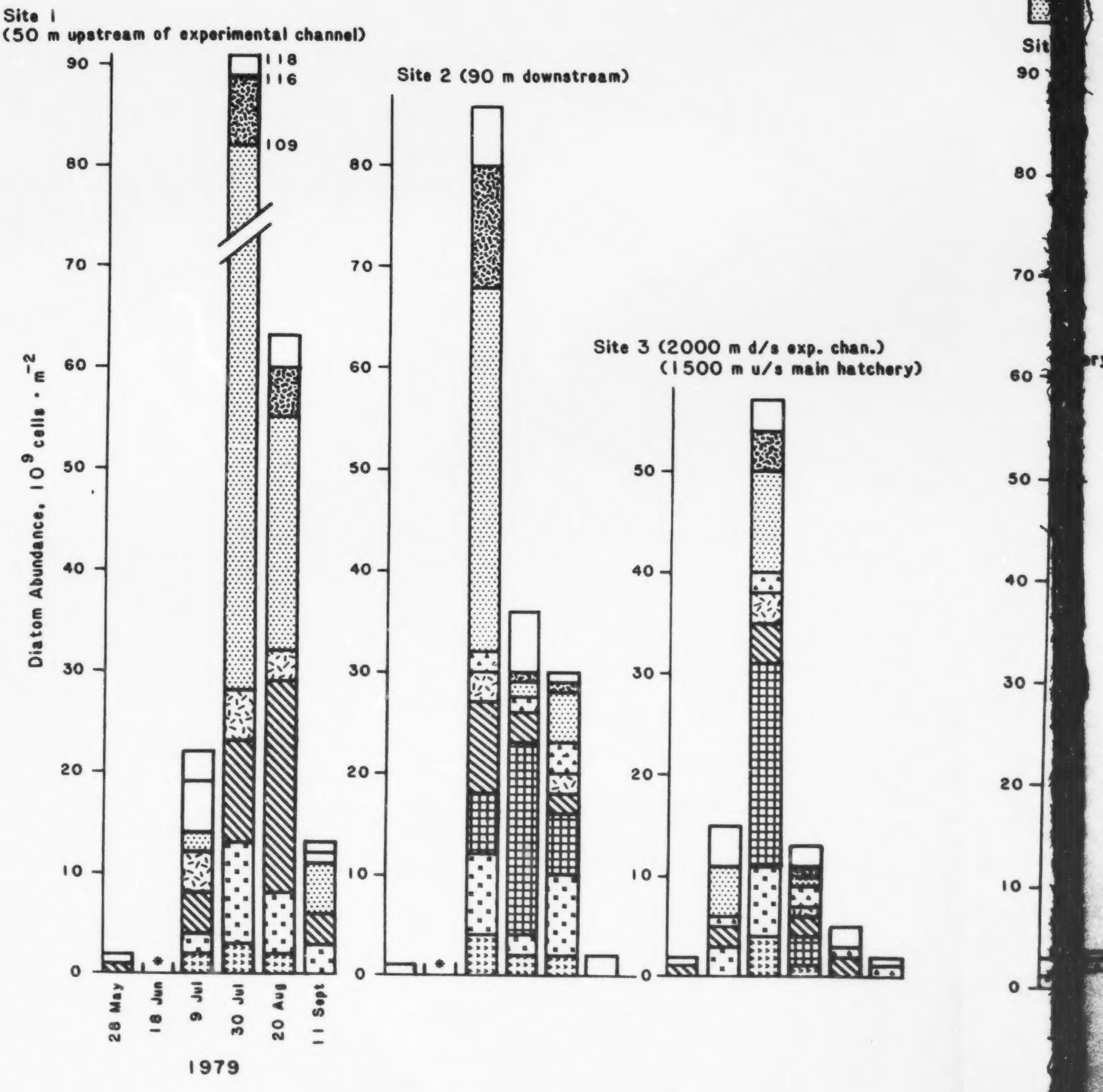
Fig. 33 Big Qualicum River – Riffle Sites

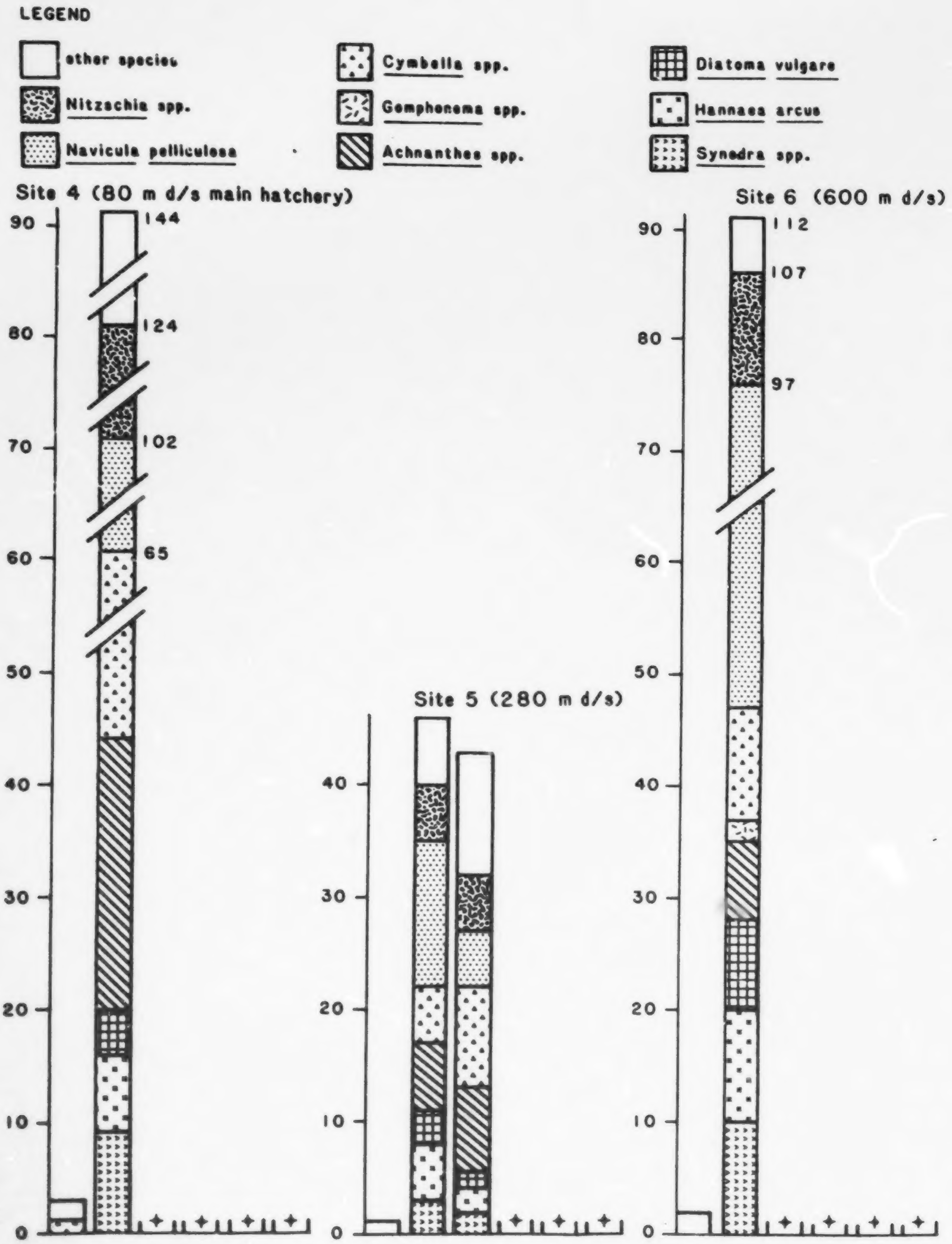
Periphyton Species Composition, % Abundance



(* – sample loss:
+ – Cladophora glomerata
drift, substrate covered)

Fig. 34 Big Qualicum River – Riffle Sites
Diatom Assemblage Size and Composition





(* - sample losses: + - Cladophora glomerata drift, substrate covered)

Fig. 35 Big Qualicum River
Benthic Invertebrate Abundance

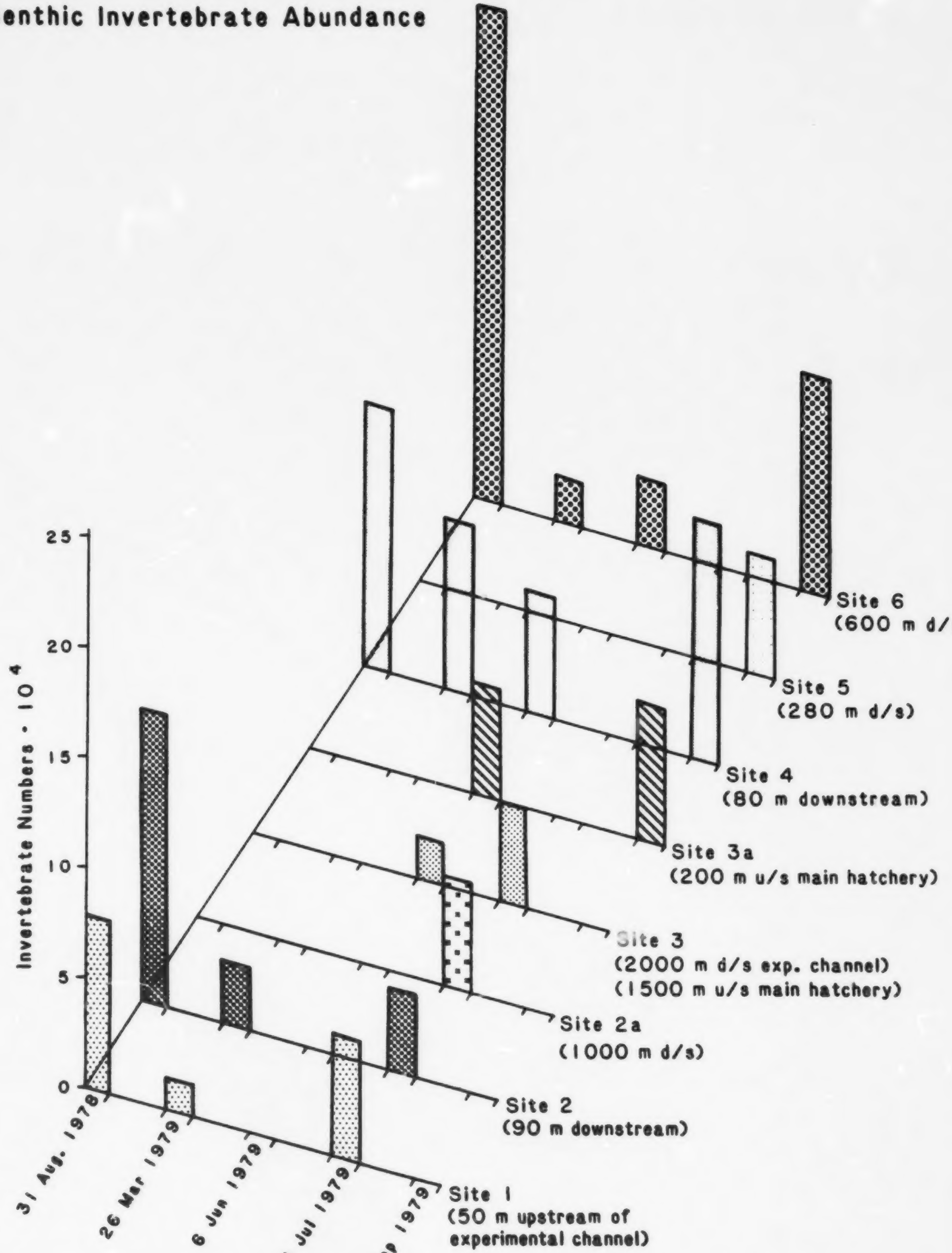
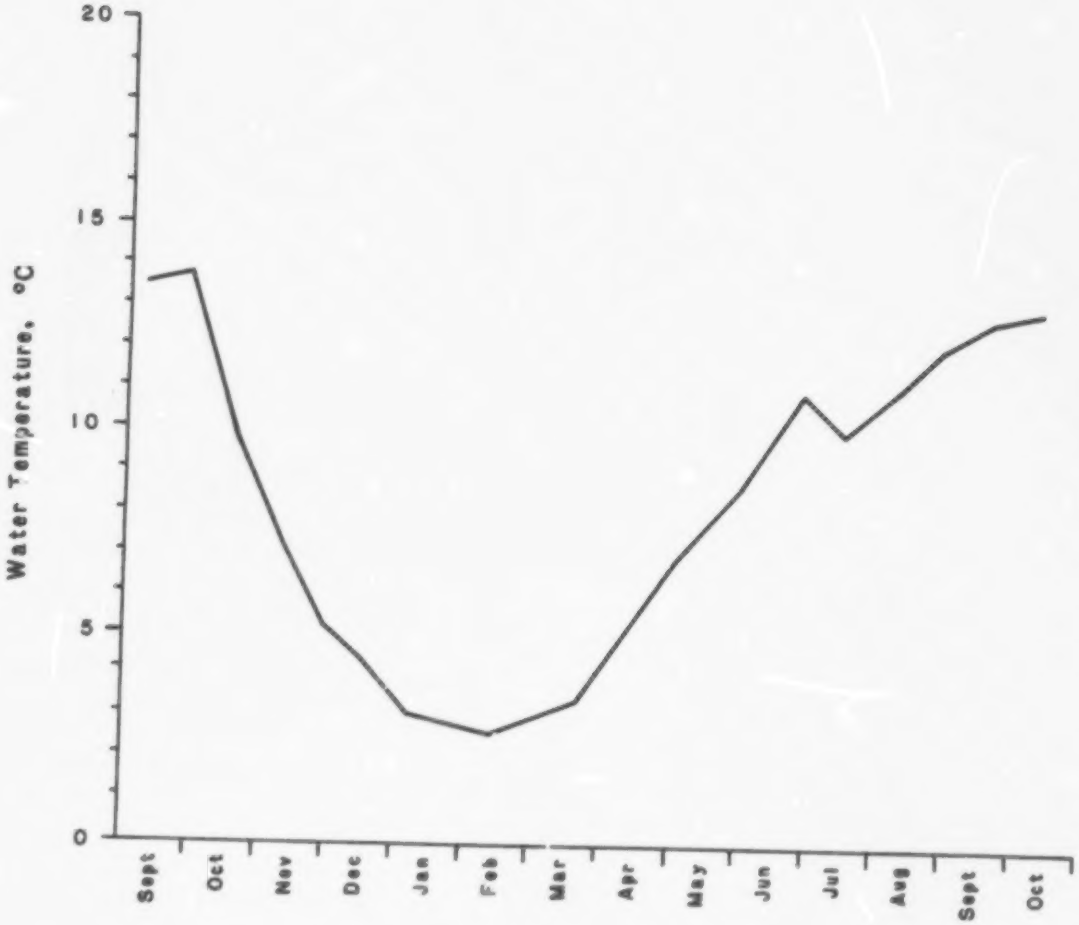


Fig. 36 Capilano River
Water Temperatures



1978 - 1979

Fig. 37 Capilano River

Water Discharge (recorded at Cleveland Dam)

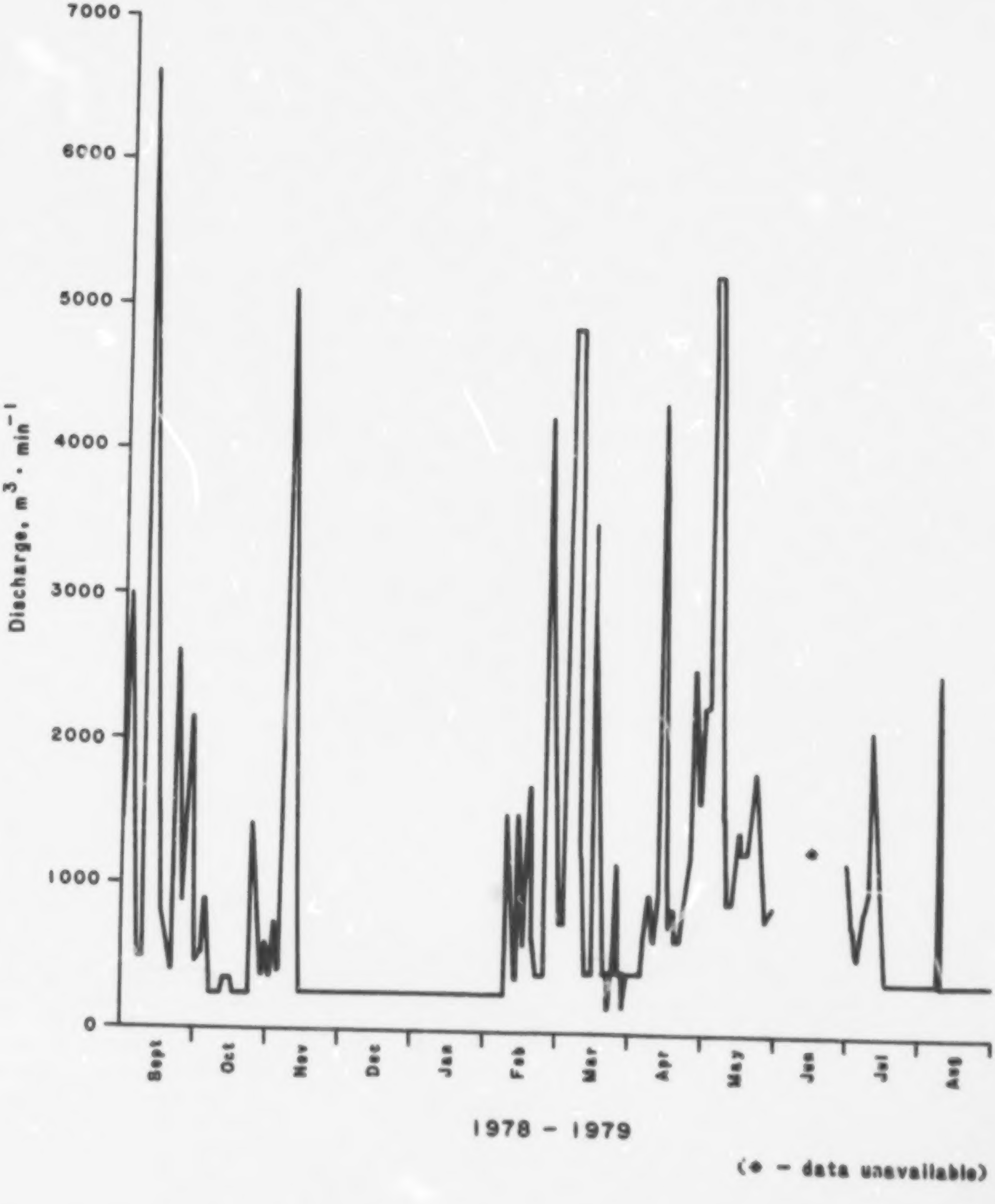
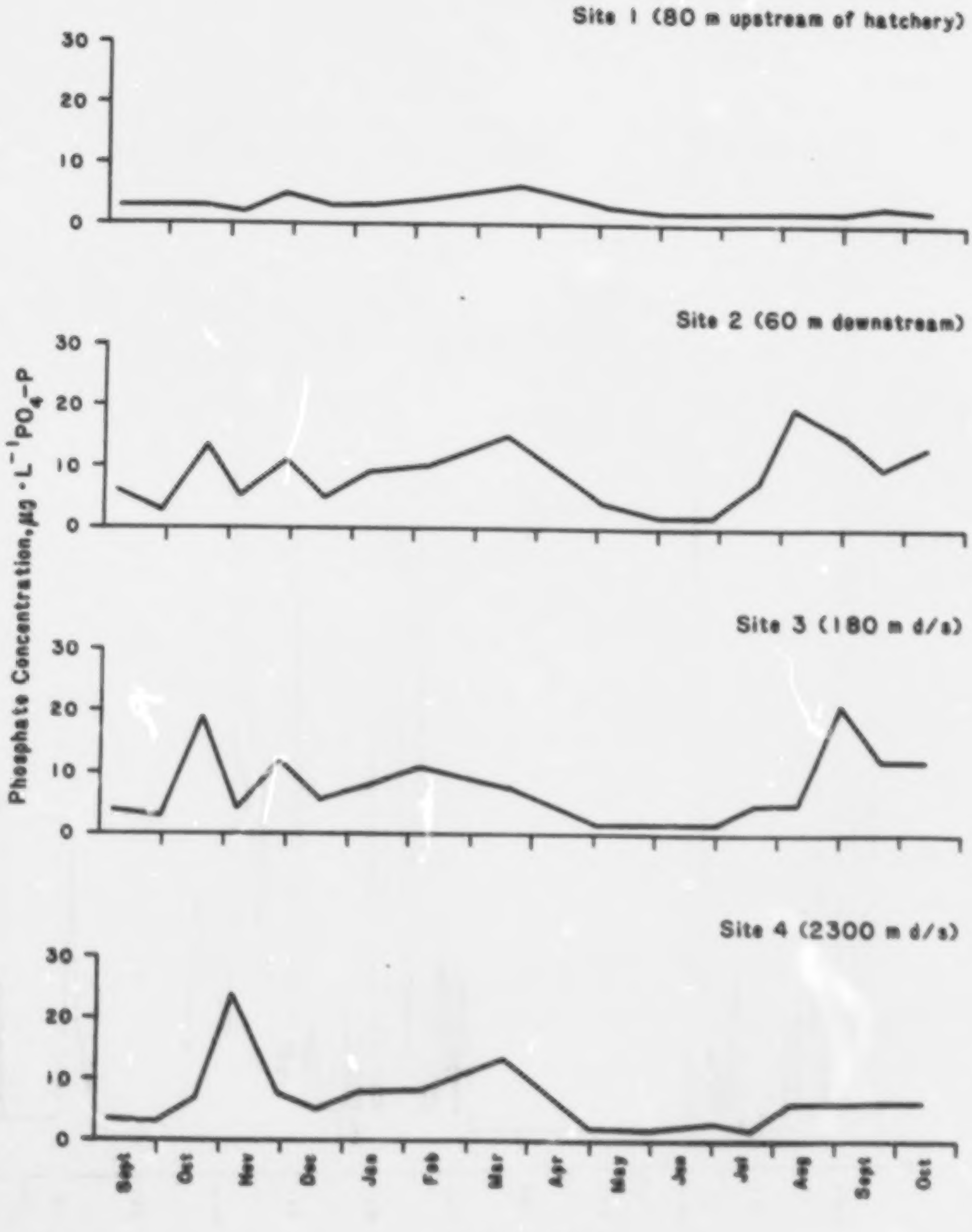


Fig. 38 Capilano River

Total Phosphate Concentrations



1978 - 1979

Fig. 39 Capilano River

Total Ammonia Concentrations — Filtered Samples

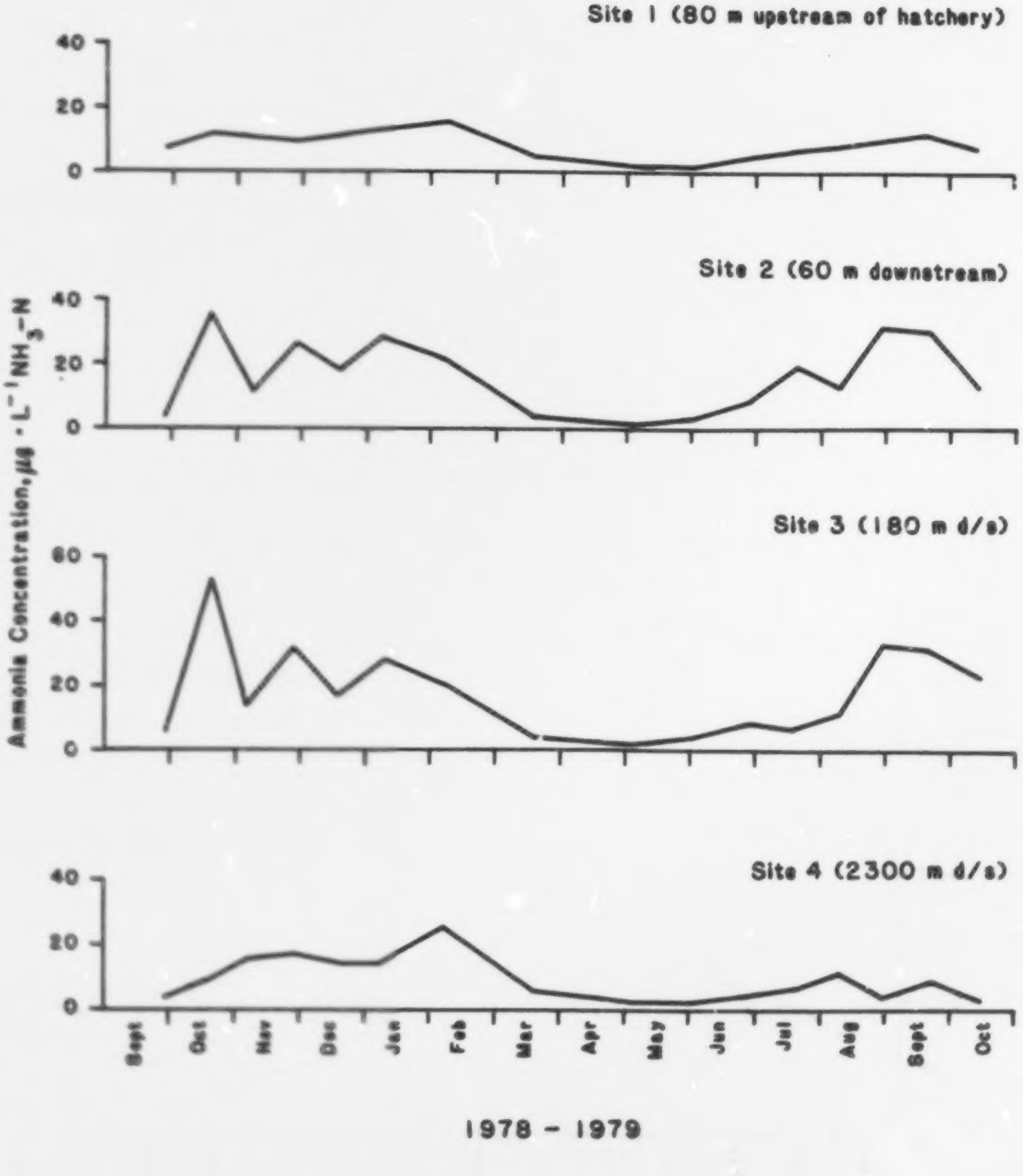


Fig. 40 Capilano River

Total Nitrate Concentrations – Filtered Samples

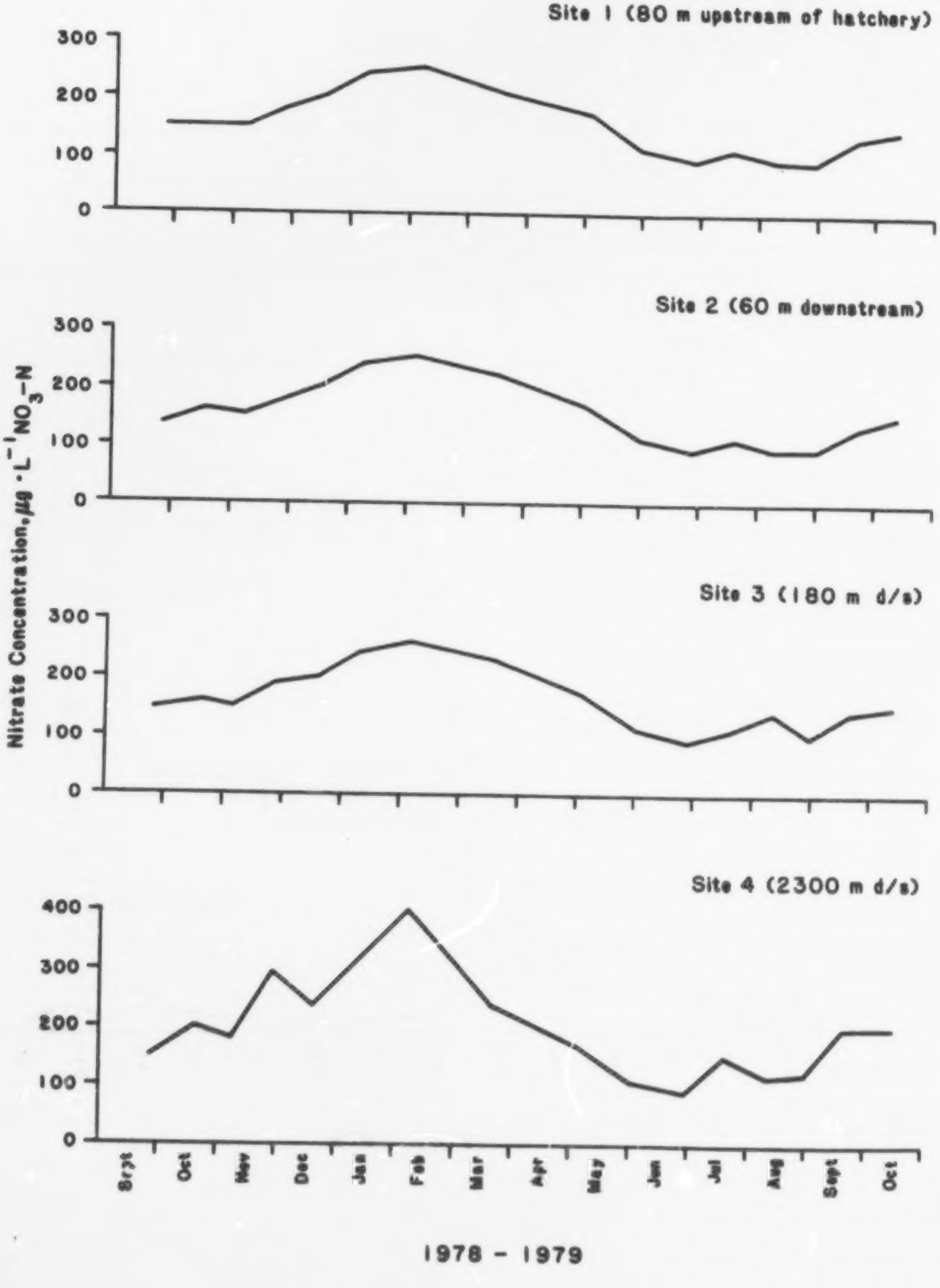
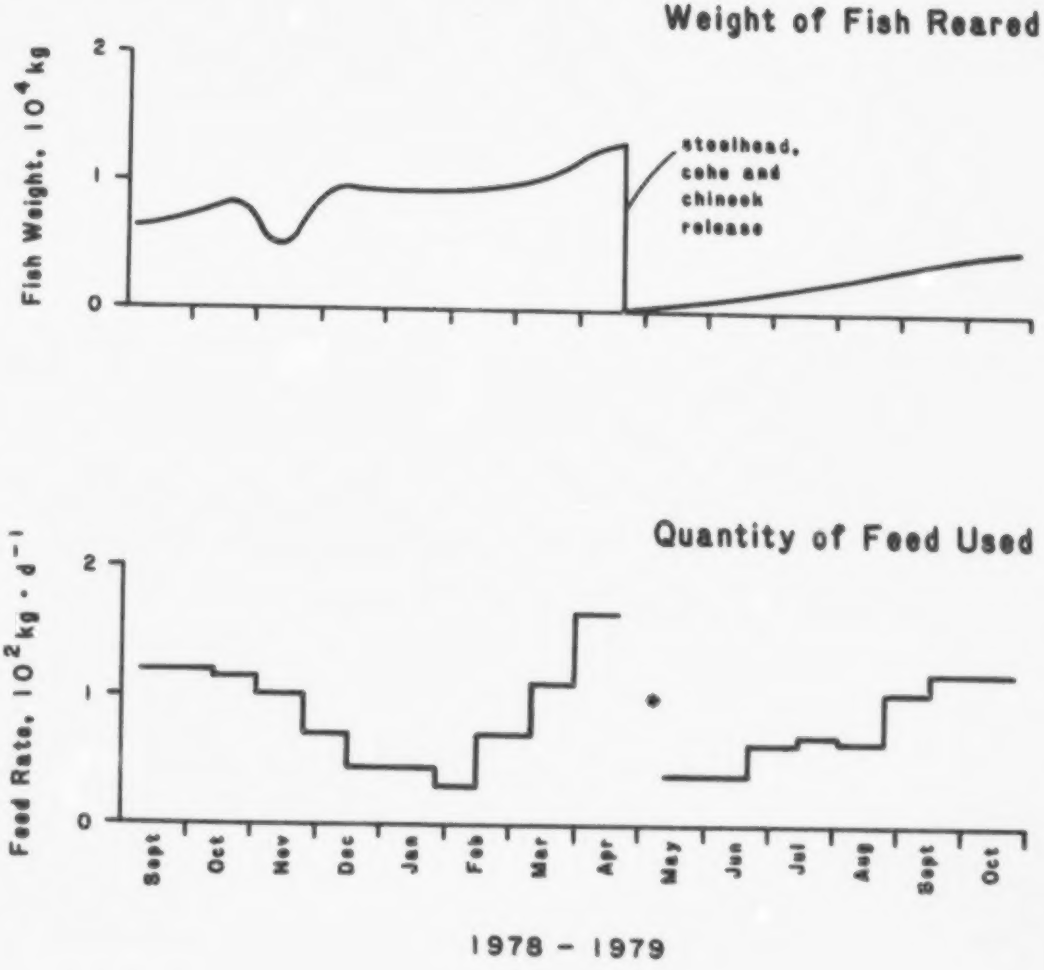
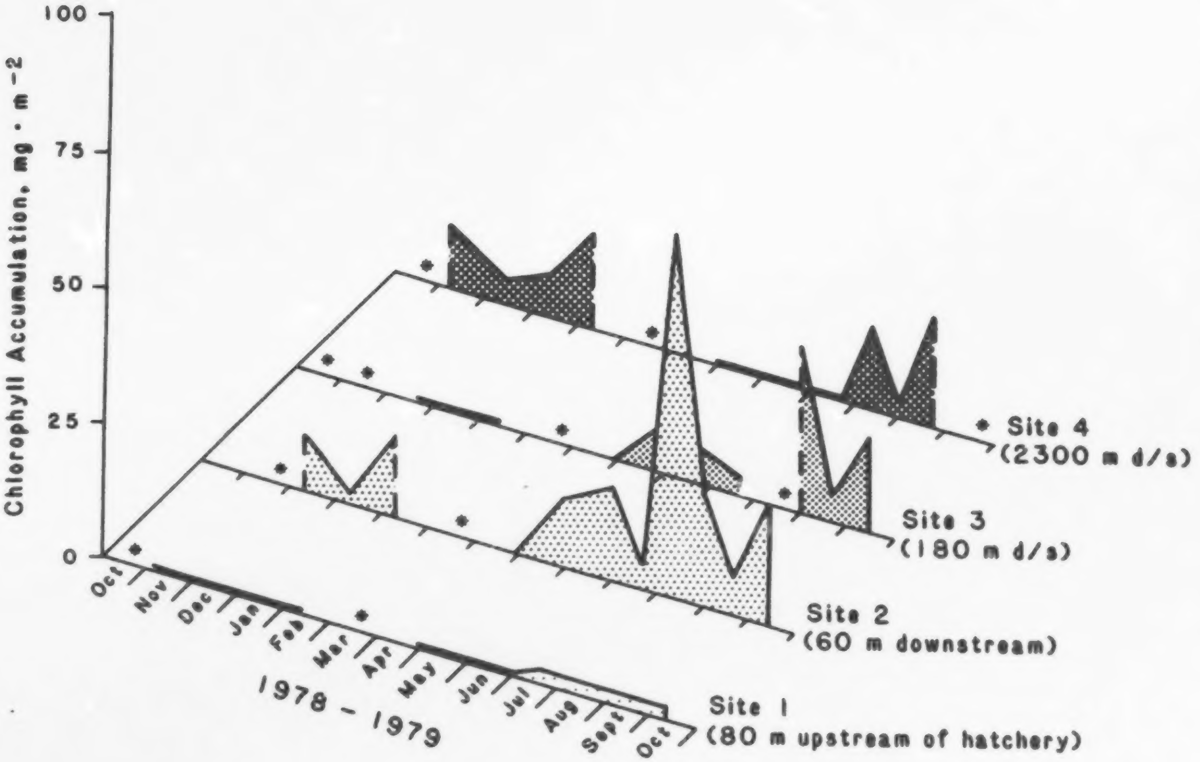


Fig. 41 Capilano River
Fish Rearing Information



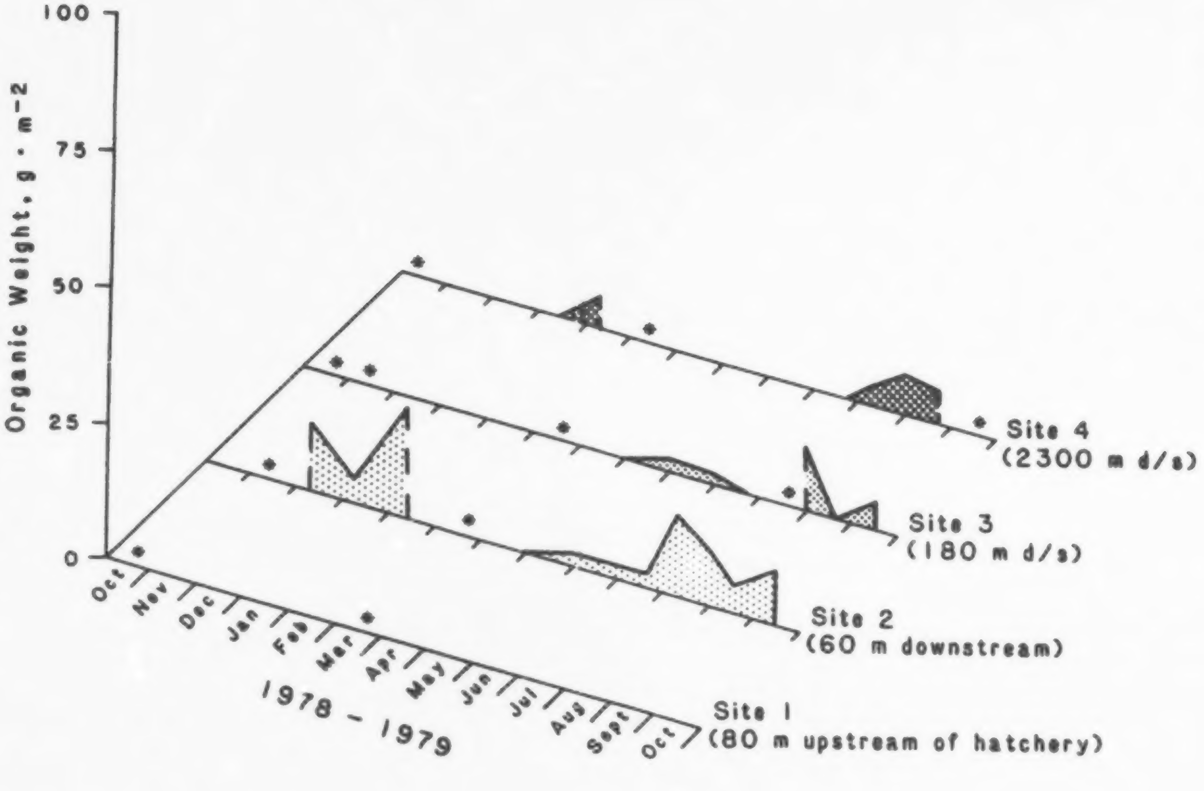
(*-data missing)

Fig. 42(a) Capilano River – Pool Sites
Periphyton Chlorophyll a



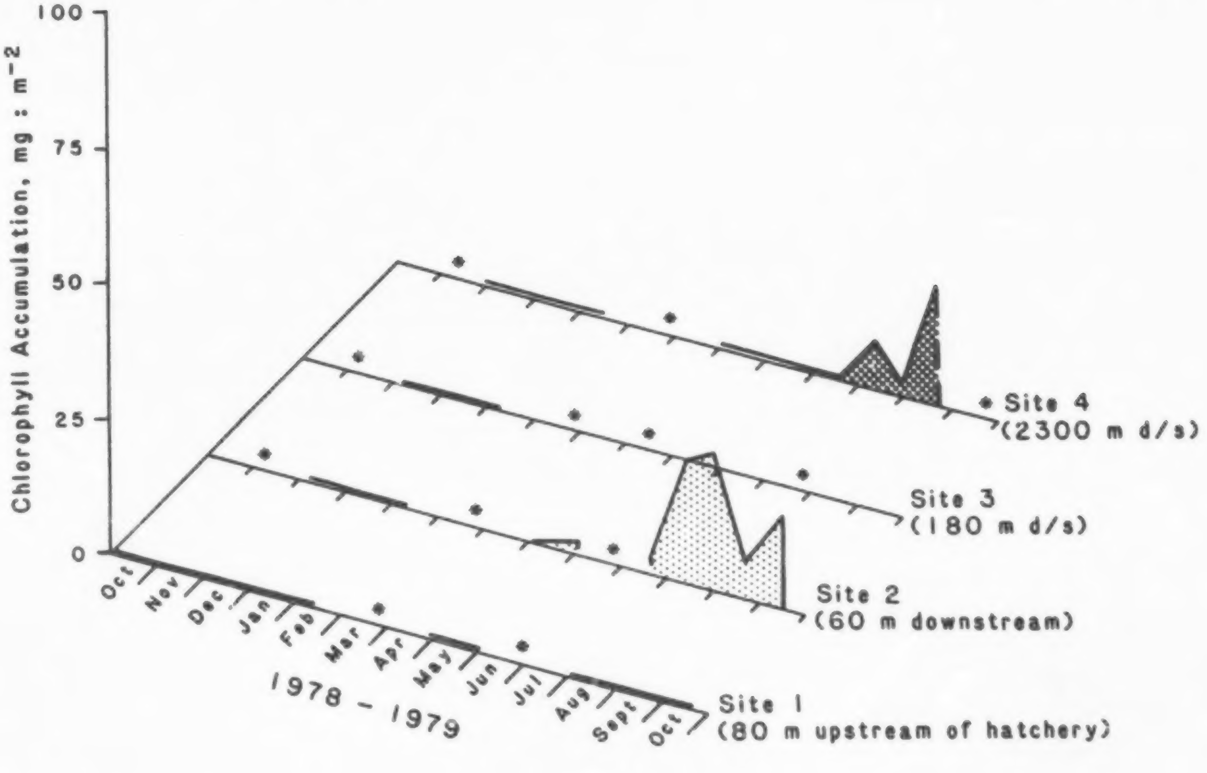
(* – flood/vandalism losses)

Fig. 42(a) cont. Capilano River – Pool Sites
Periphyton Organic Weight



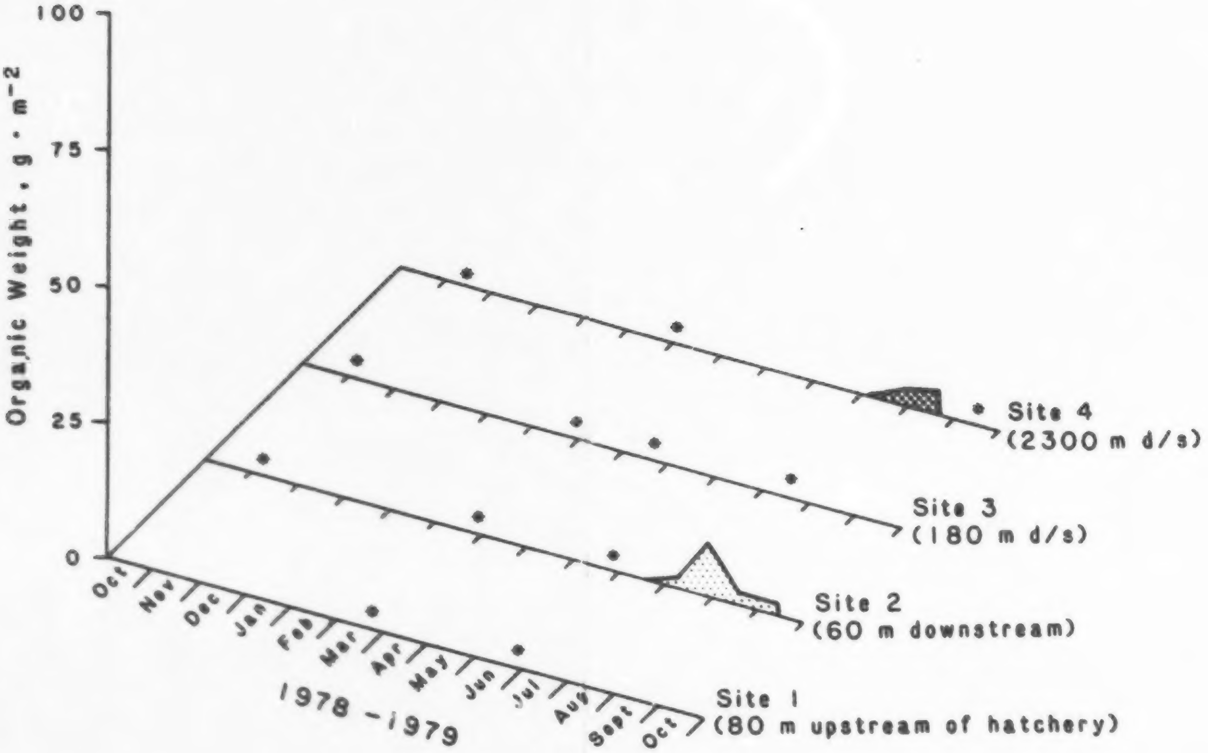
(* – flood/vandalism losses)

Fig. 42(b) Capilano River – Riffle Sites
Periphyton Chlorophyll a



(* – flood losses)

Fig. 42(b) cont. Capilano River – Riffle Sites
Periphyton Organic Weight



(* – flood losses)

Fig. 43(a) Capilano River – Pool Sites
Periphyton Species Composition, % Abundance

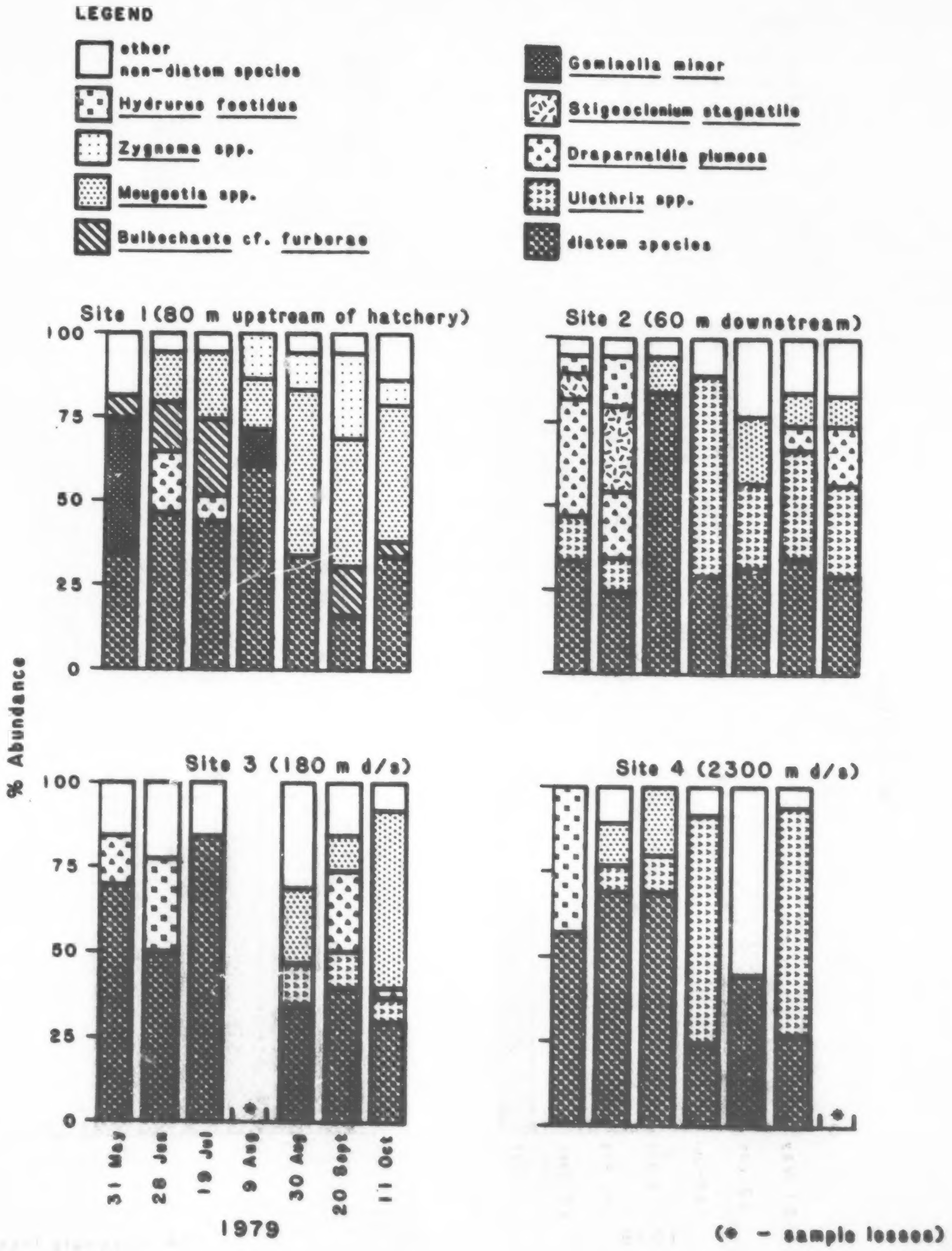


Fig. 43(b) Capilano River – Riffle Sites
Periphyton Species Composition, % Abundance

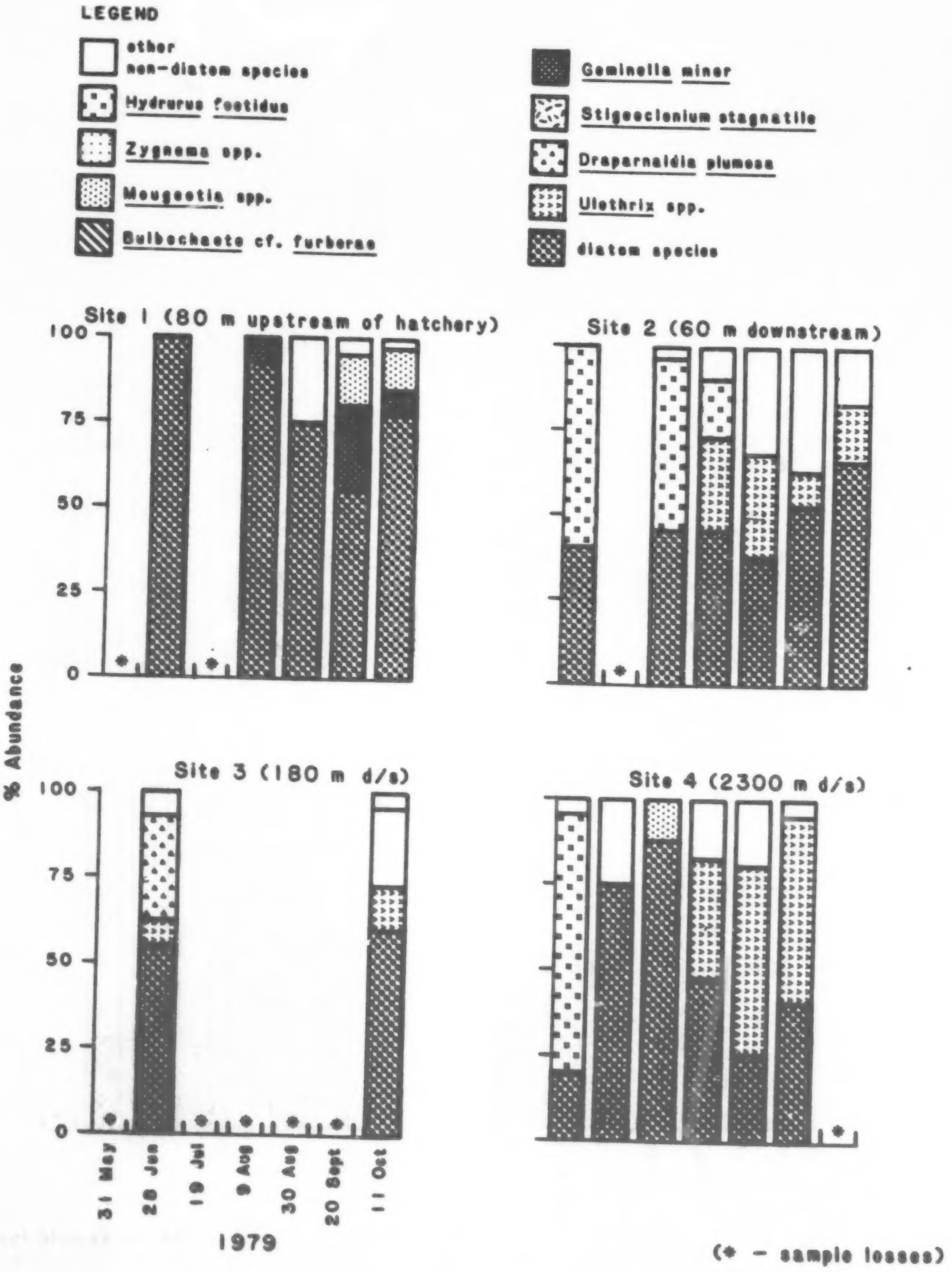
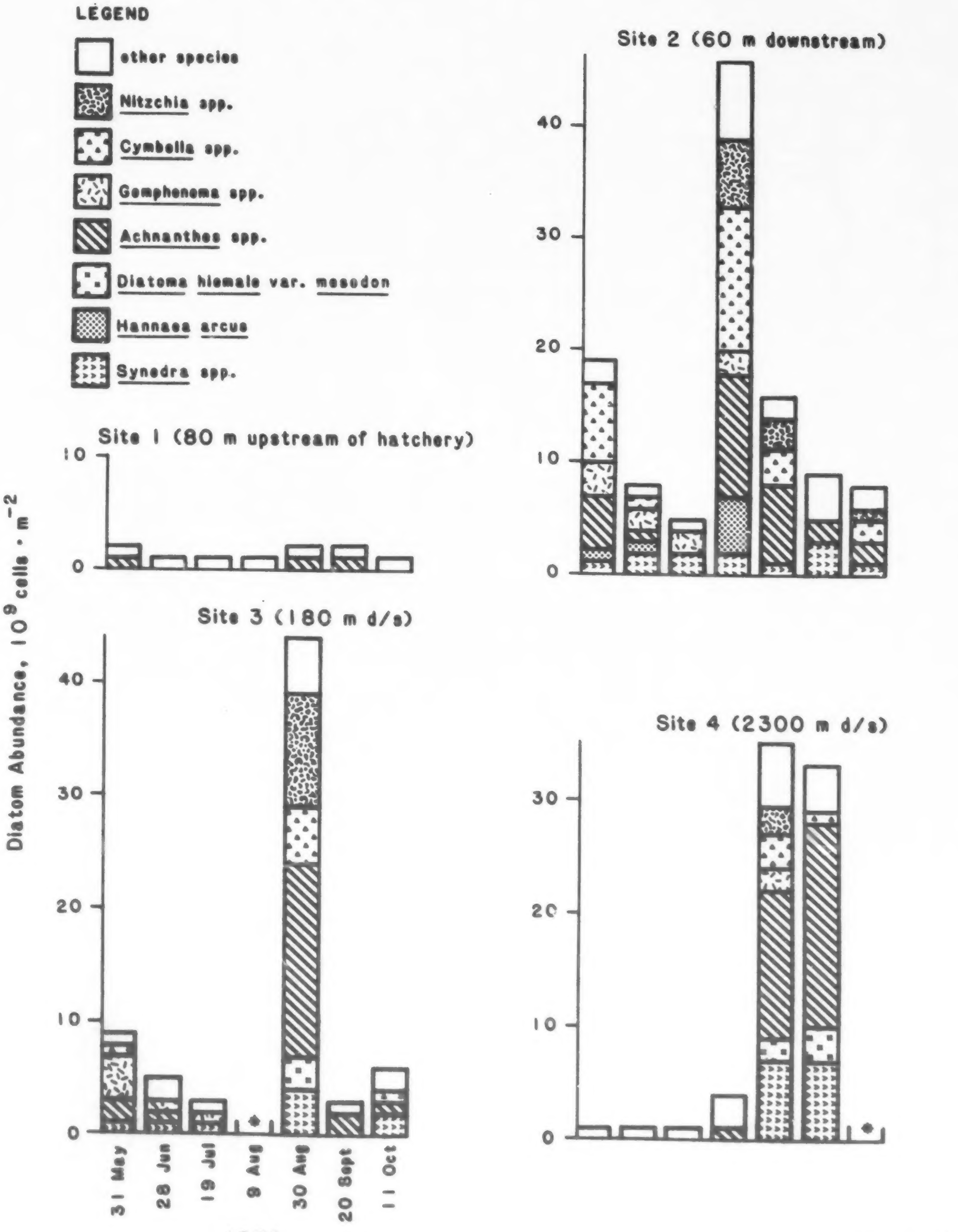


Fig. 44(a) Capilano River – Pool Sites
Diatom Assemblage Size and Composition



(* – sample losses)

Fig. 44(b) Capilano River – Riffle Sites
Diatom Assemblage Size and Composition

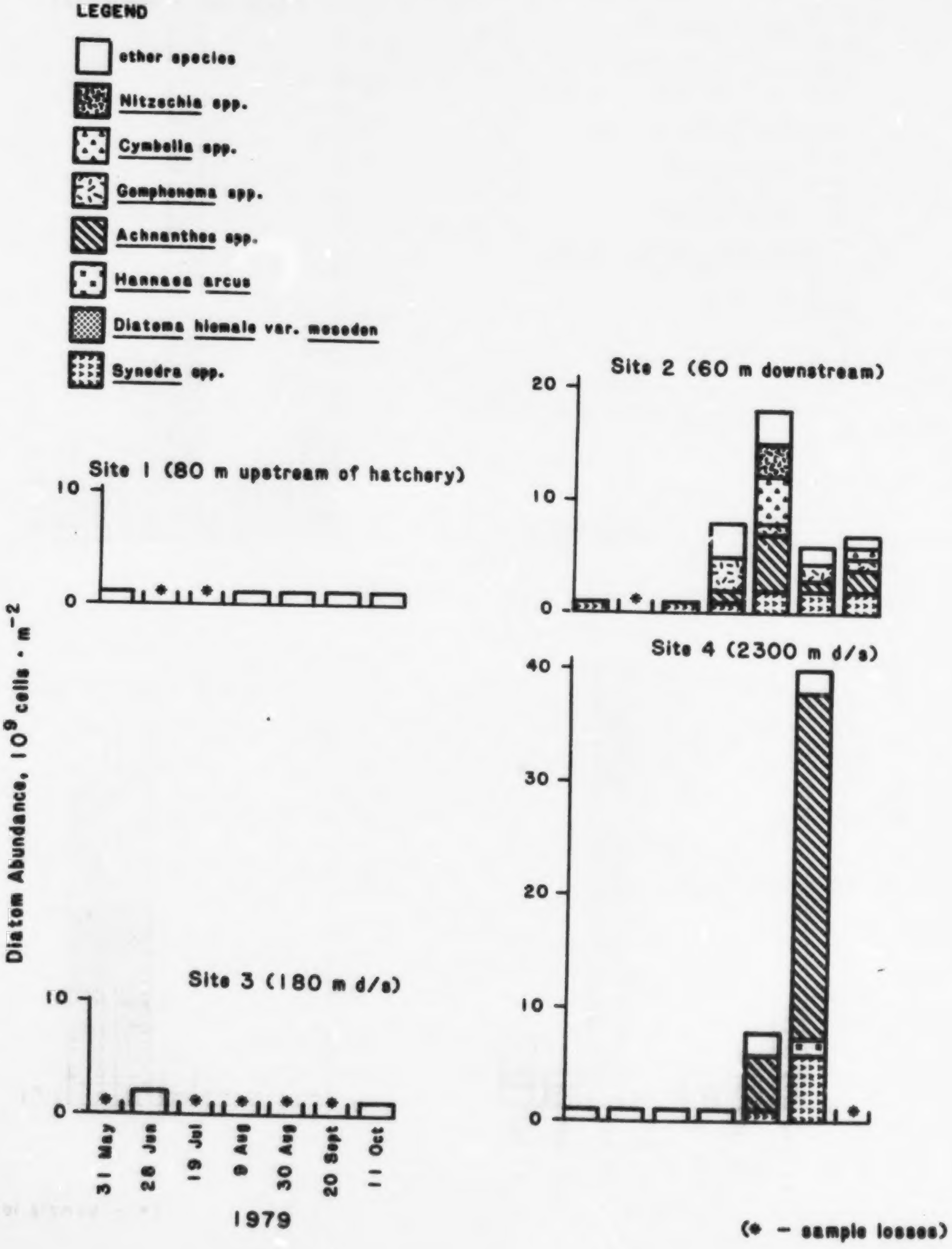


Fig. 45 Capilano River
Benthic Invertebrate Abundance

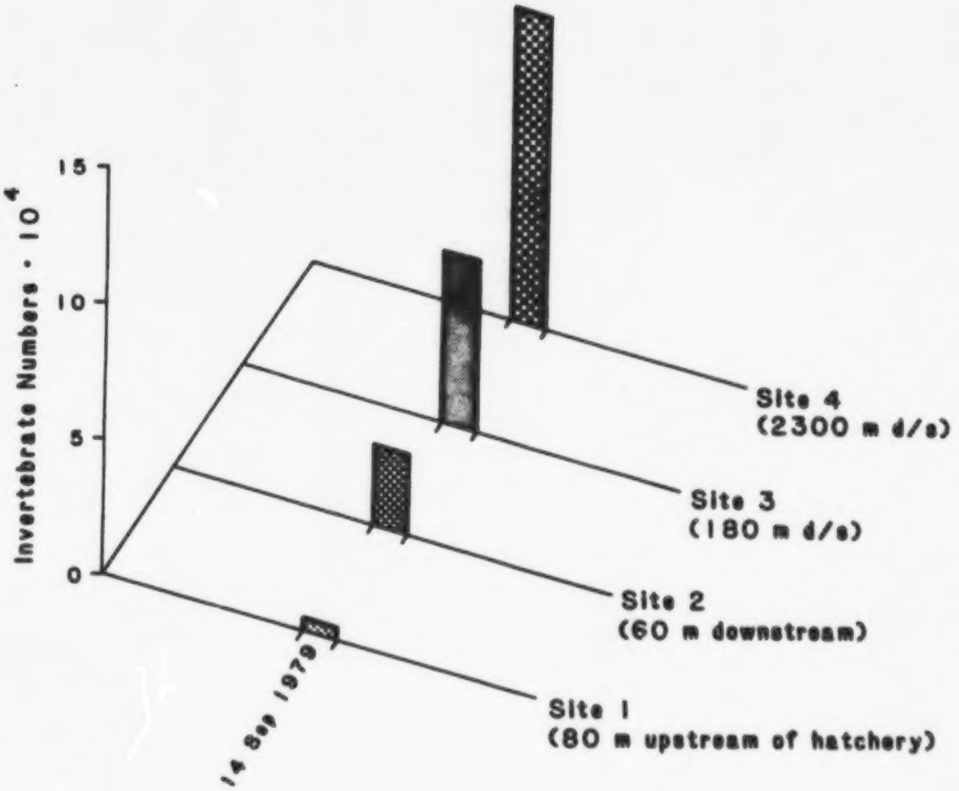


Fig. 46 Chilliwack River
Nutrient Concentrations

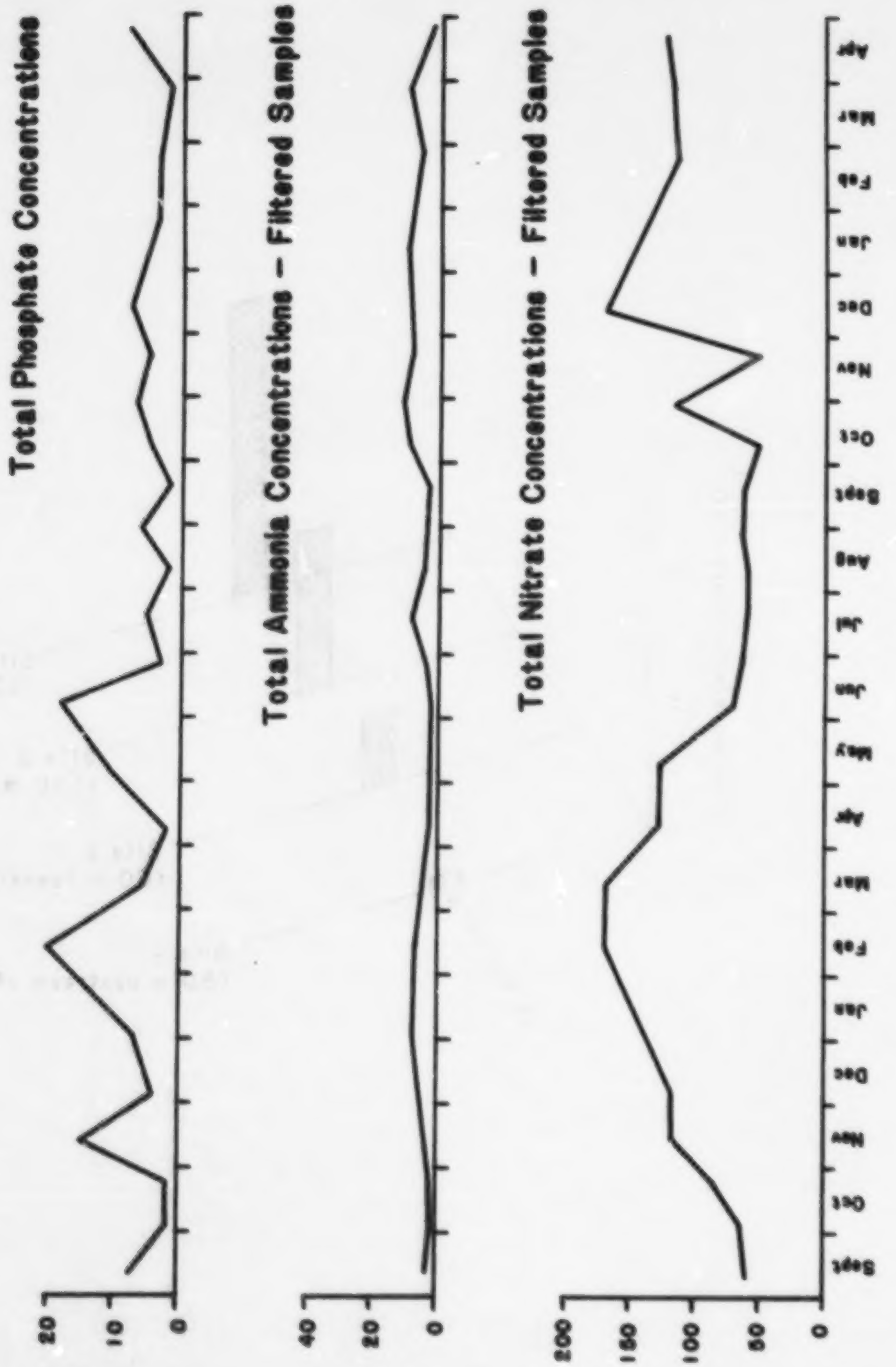
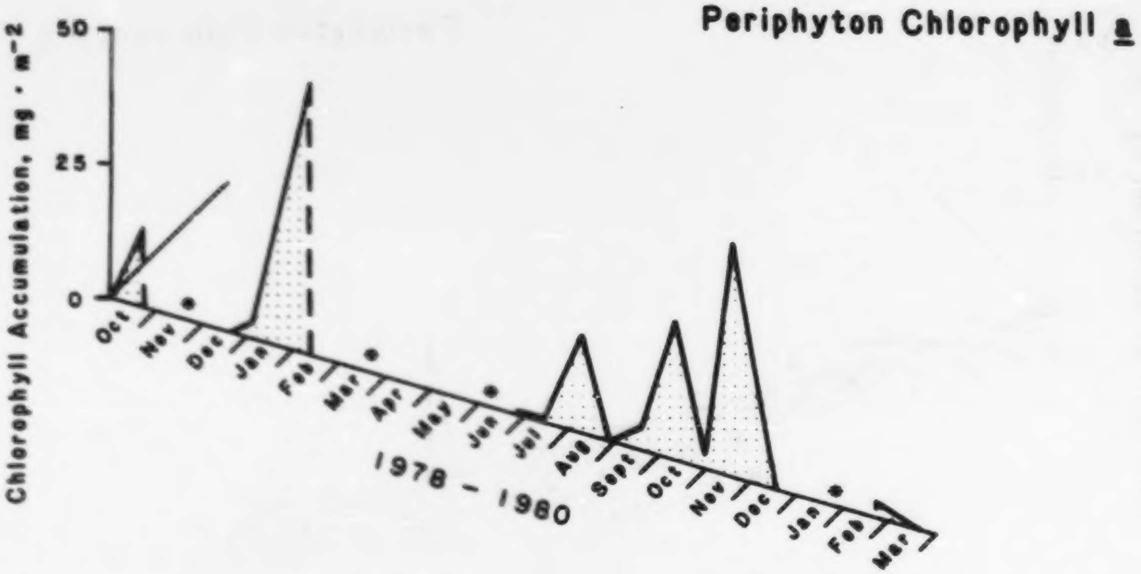
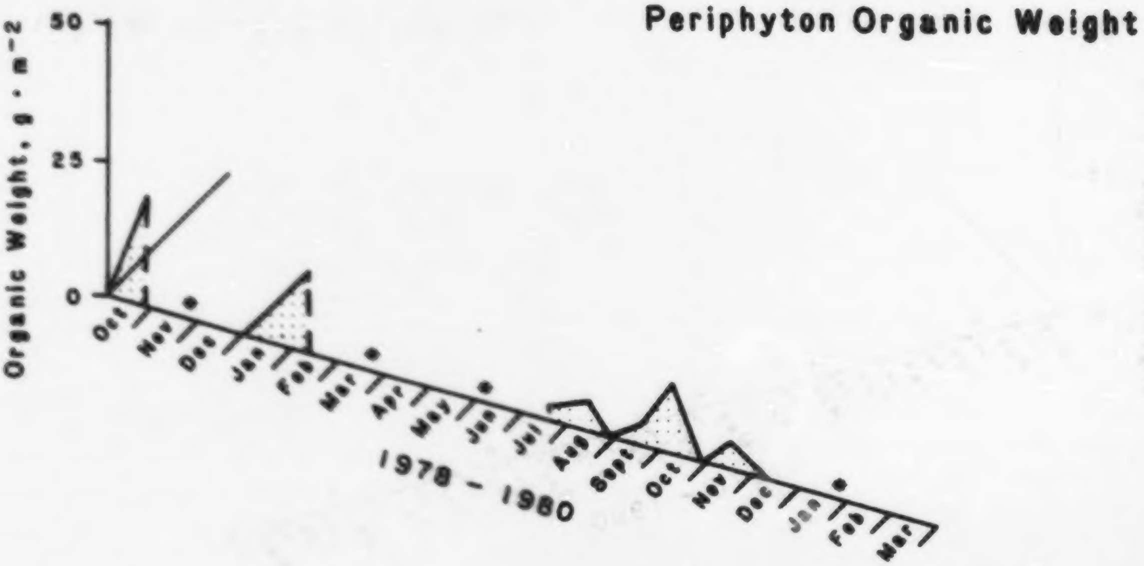


Fig. 47(a) Chilliwack River – Pool Site



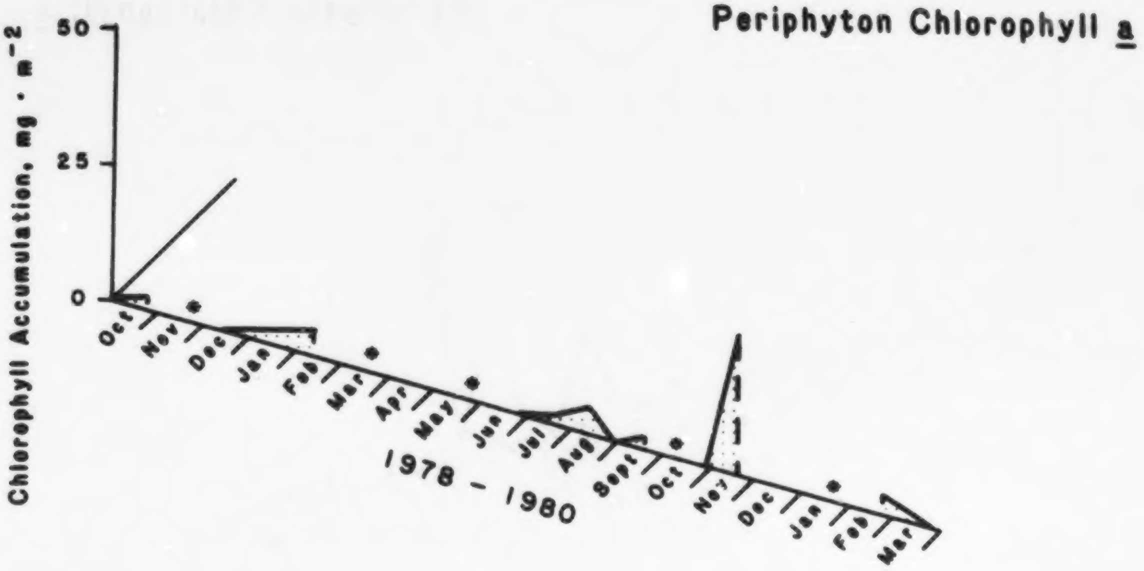
Periphyton Chlorophyll a



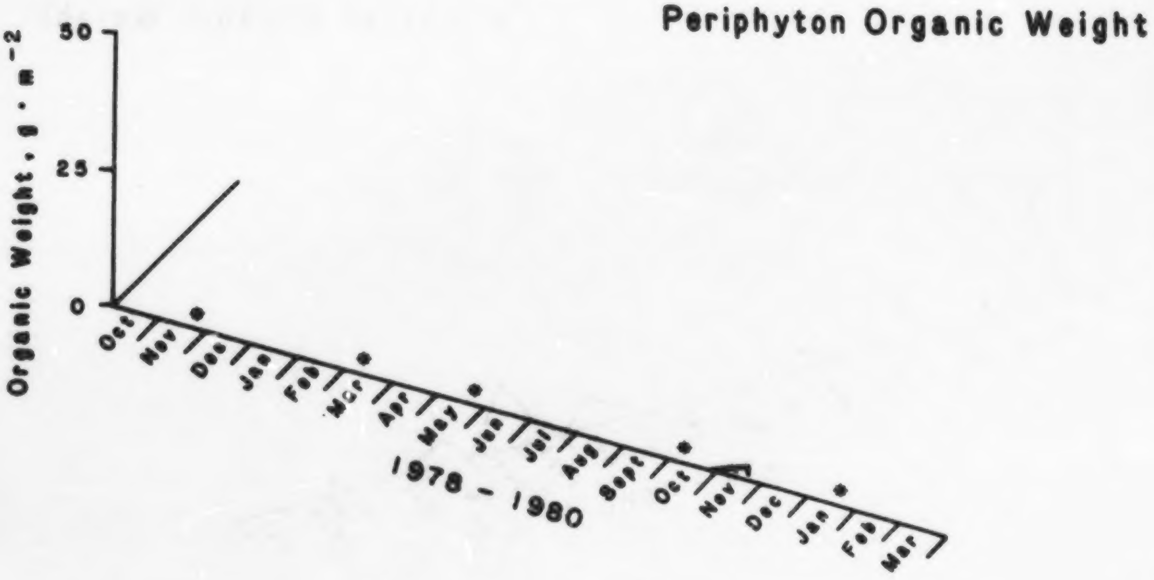
Periphyton Organic Weight

(* – flood/vandalism losses)

Fig. 47(b) Chilliwack River – Riffle Site



Periphyton Chlorophyll a

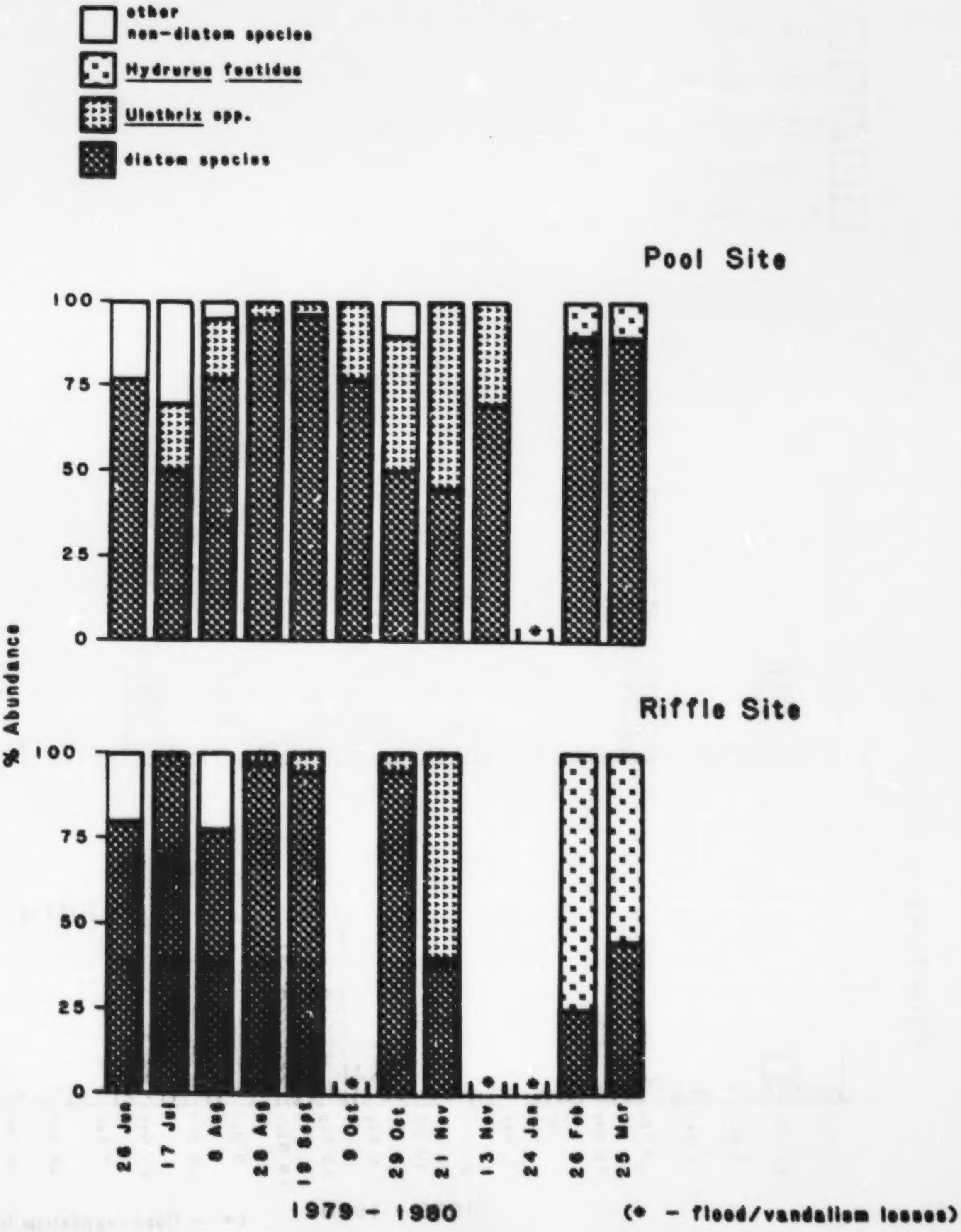


Periphyton Organic Weight

(* - flood/vandalism losses)

Fig. 48 Chilliwack River

Periphyton Species Composition, % Abundance



(* - flood/vandalism losses)

Fig. 49 Chilliwack River

Diatom Assemblage Size and Composition

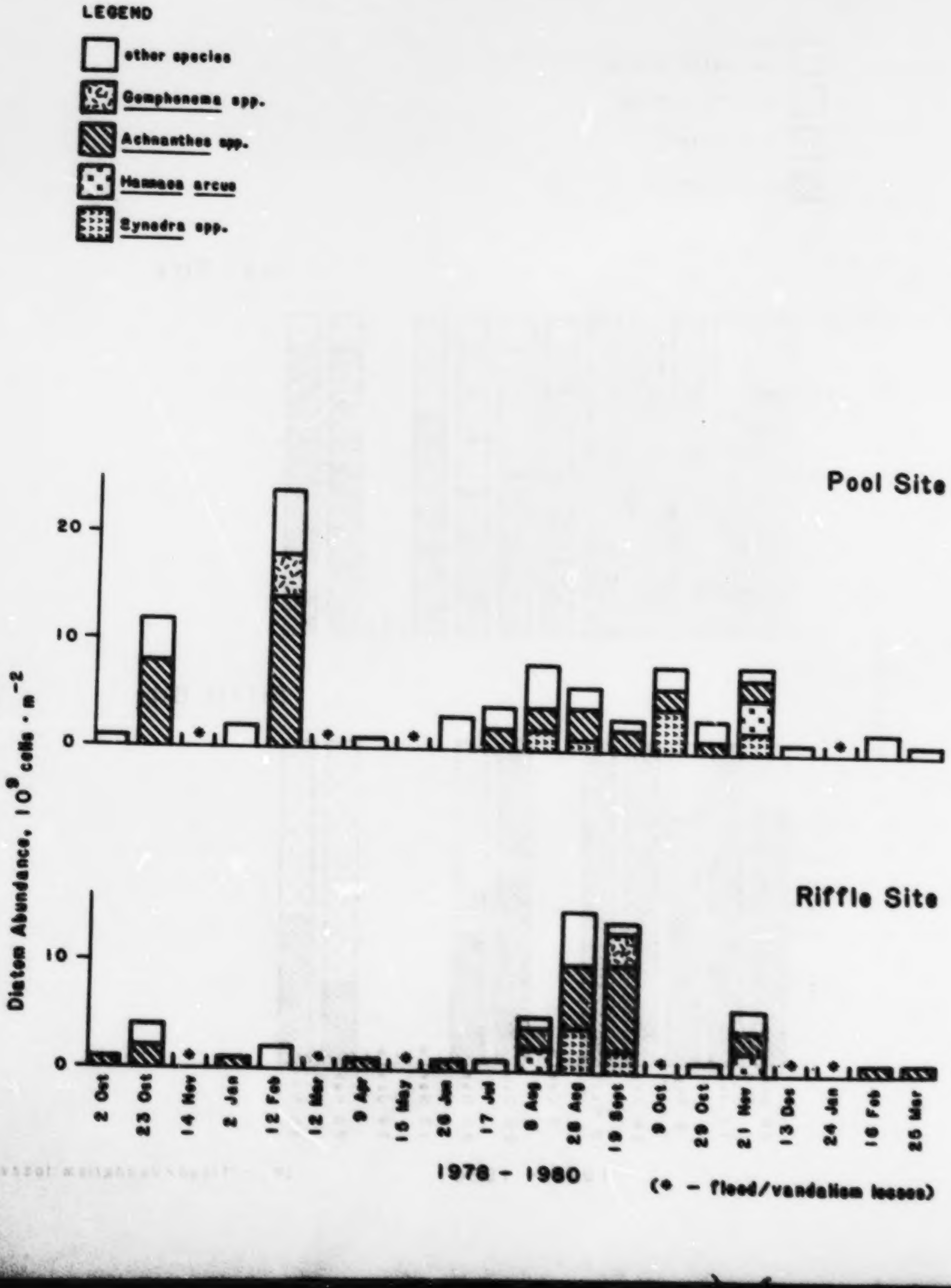
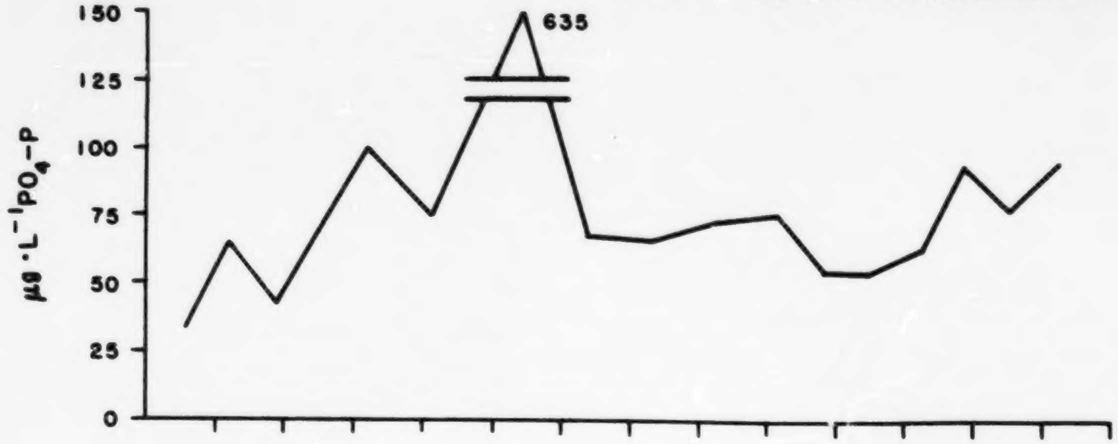
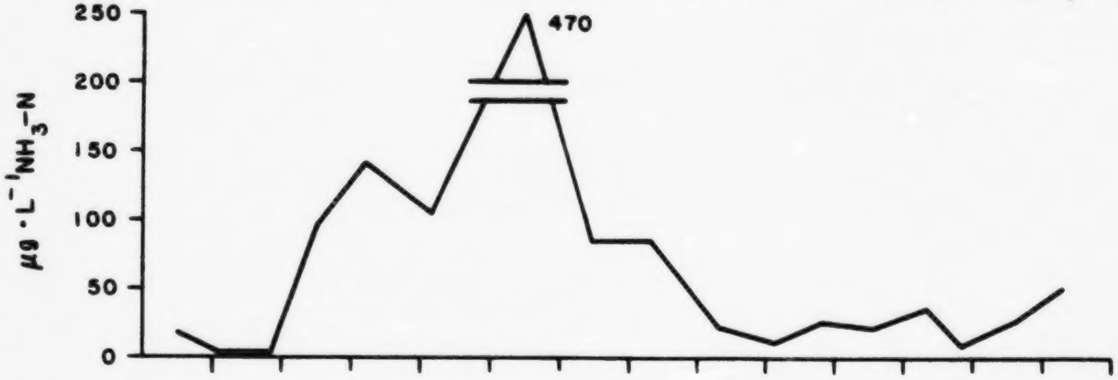


Fig. 50 Nicola River
Nutrient Concentrations

Total Phosphate Concentrations



Total Ammonia Concentrations - Filtered Samples



Total Nitrate Concentrations - Filtered Samples

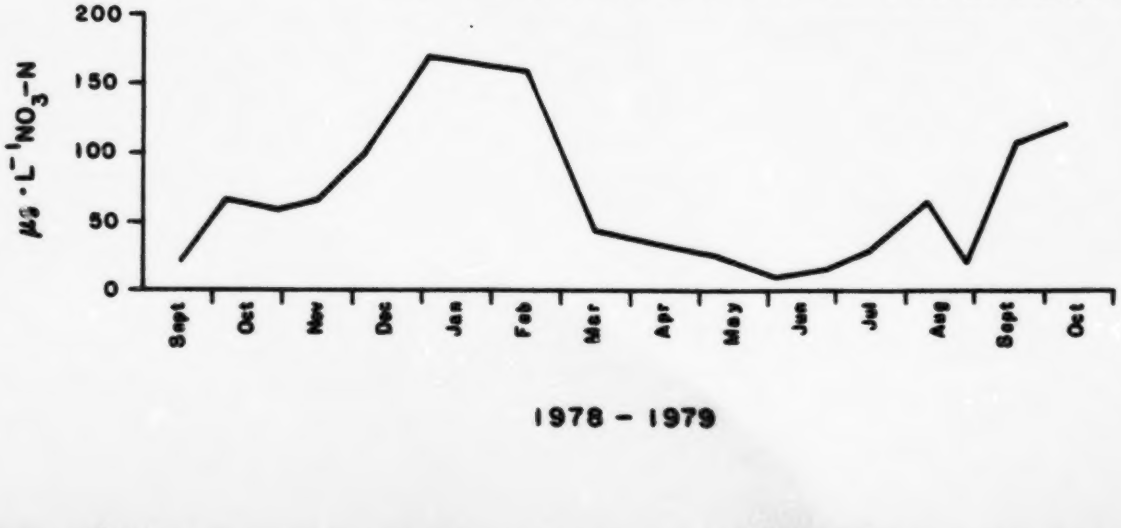
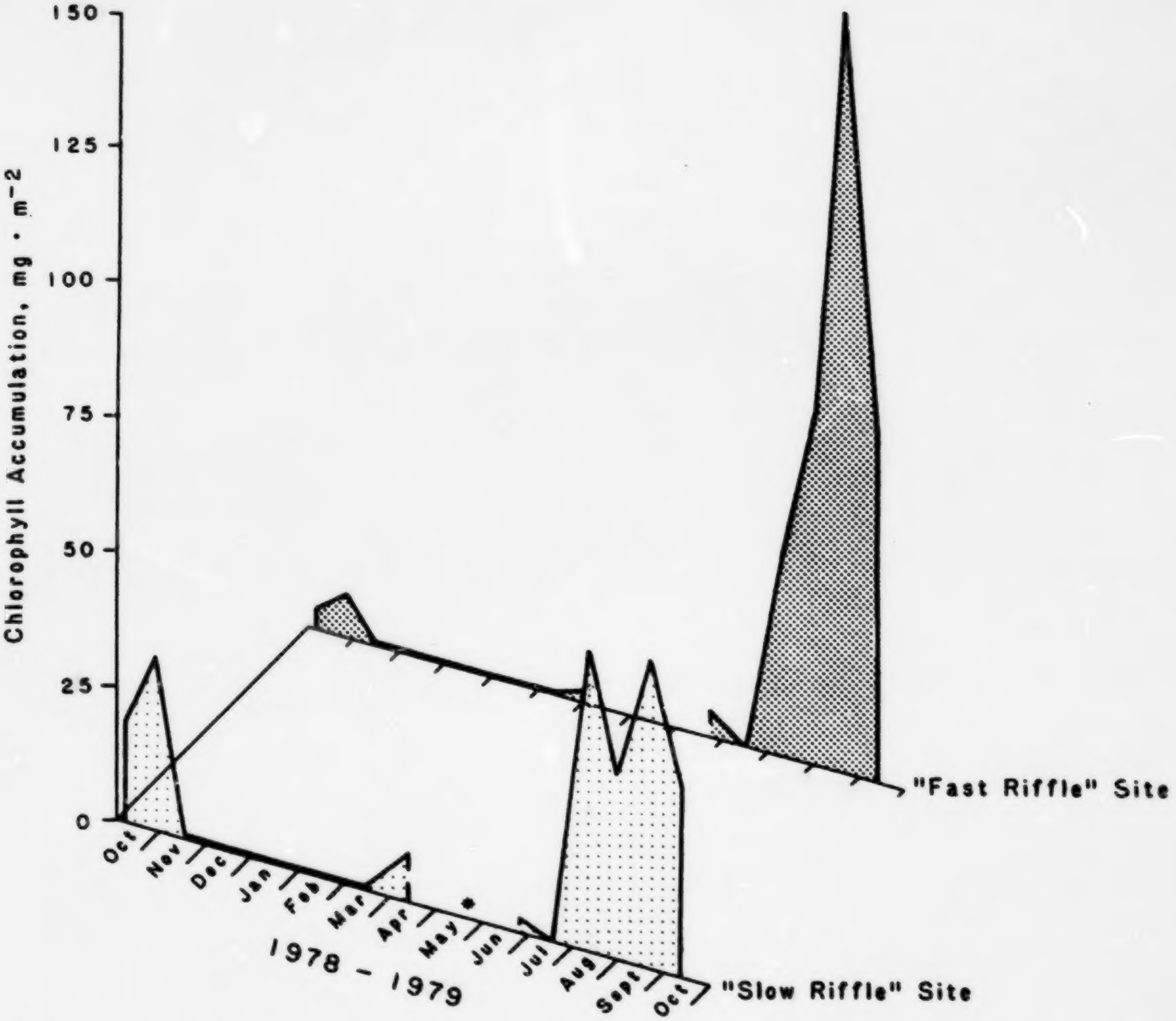


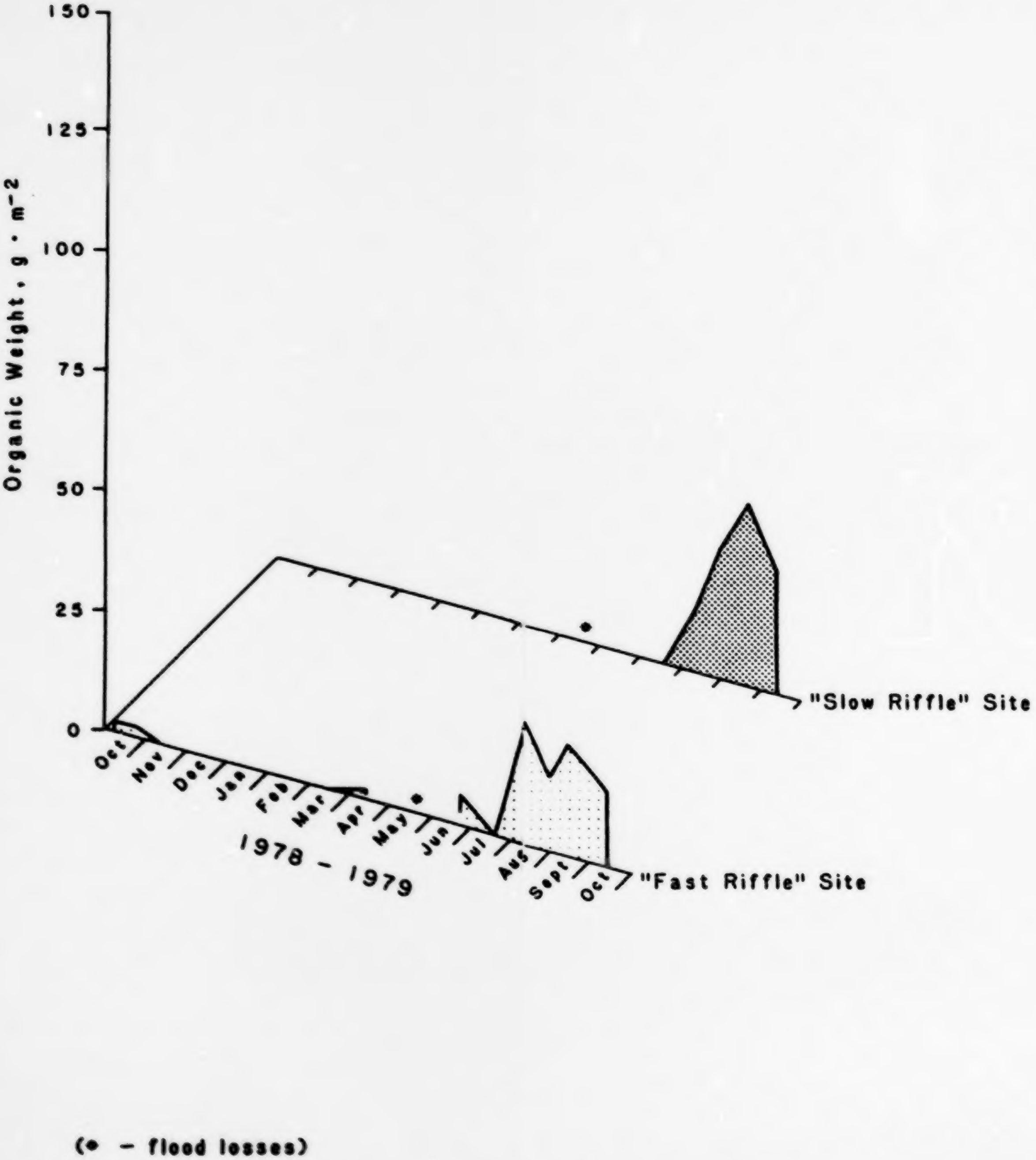
Fig. 51 Nicola River – Riffle Sites

Periphyton Chlorophyll a



(* – flood losses)

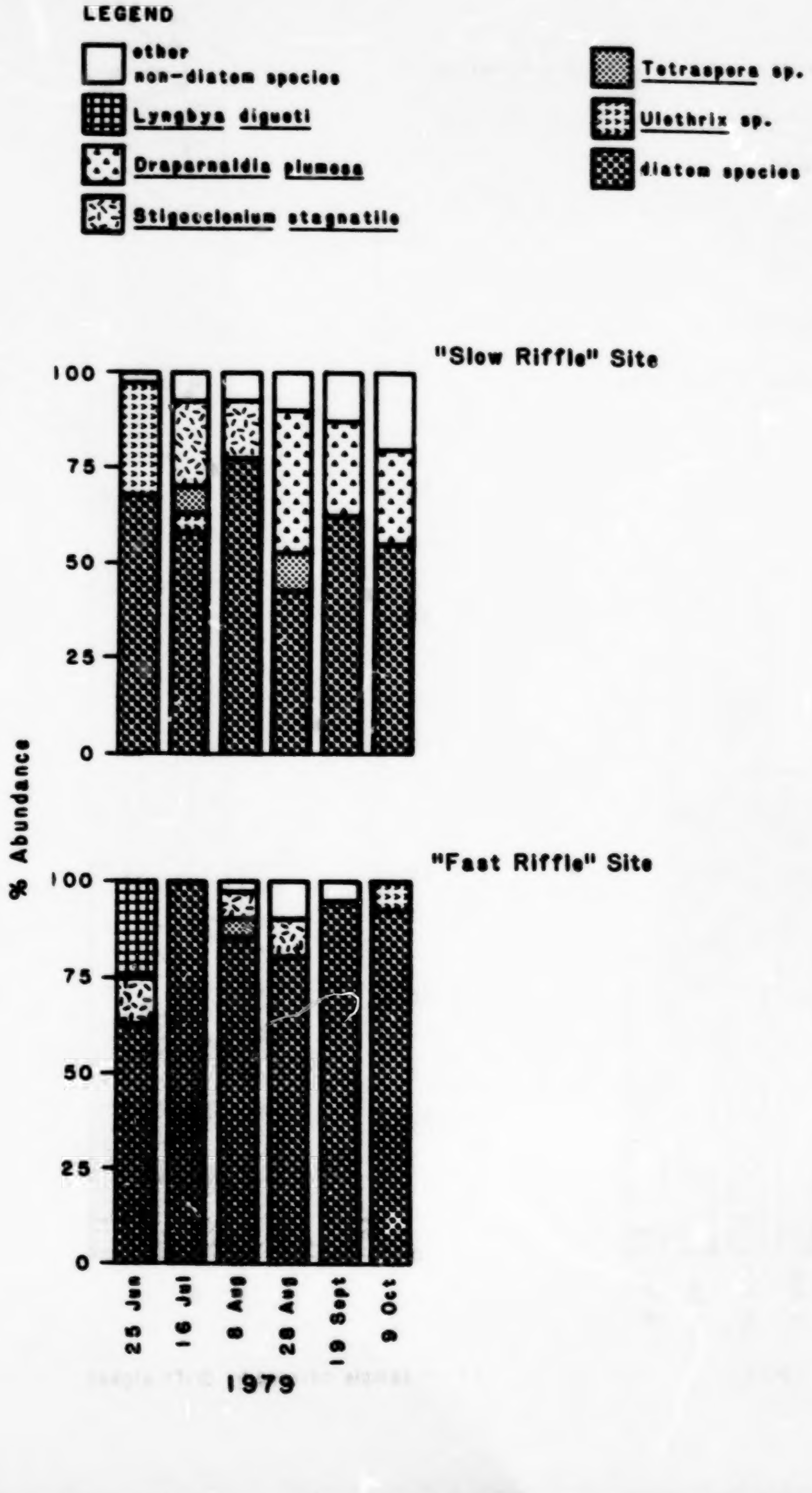
Fig. 51 cont. Nicola River - Riffle Sites
Periphyton Organic Weight



(• - flood losses)

Fig. 52 Nicola River

Periphyton Species Composition, % Abundance

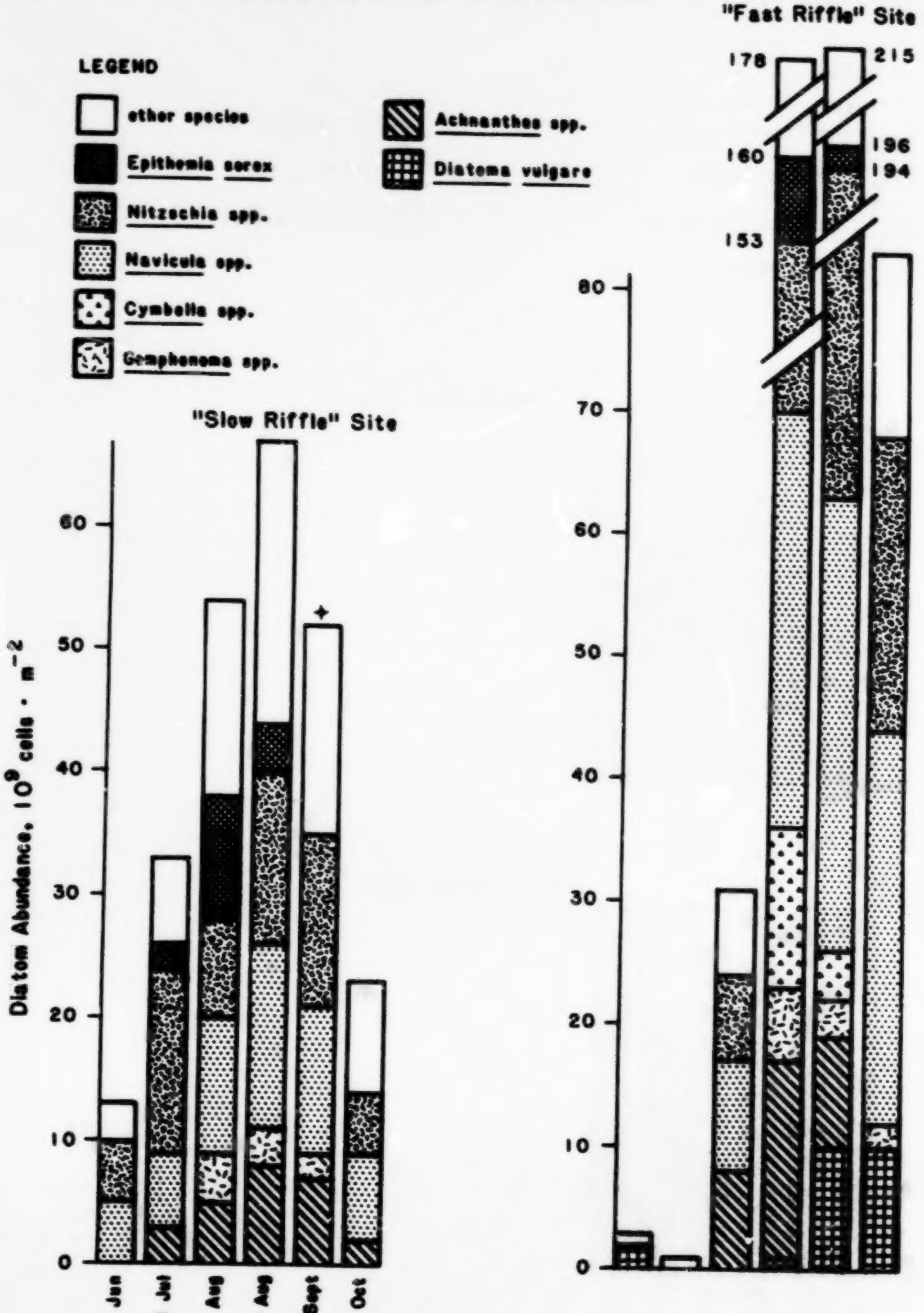


"Slow Riffle" Site

"Fast Riffle" Site

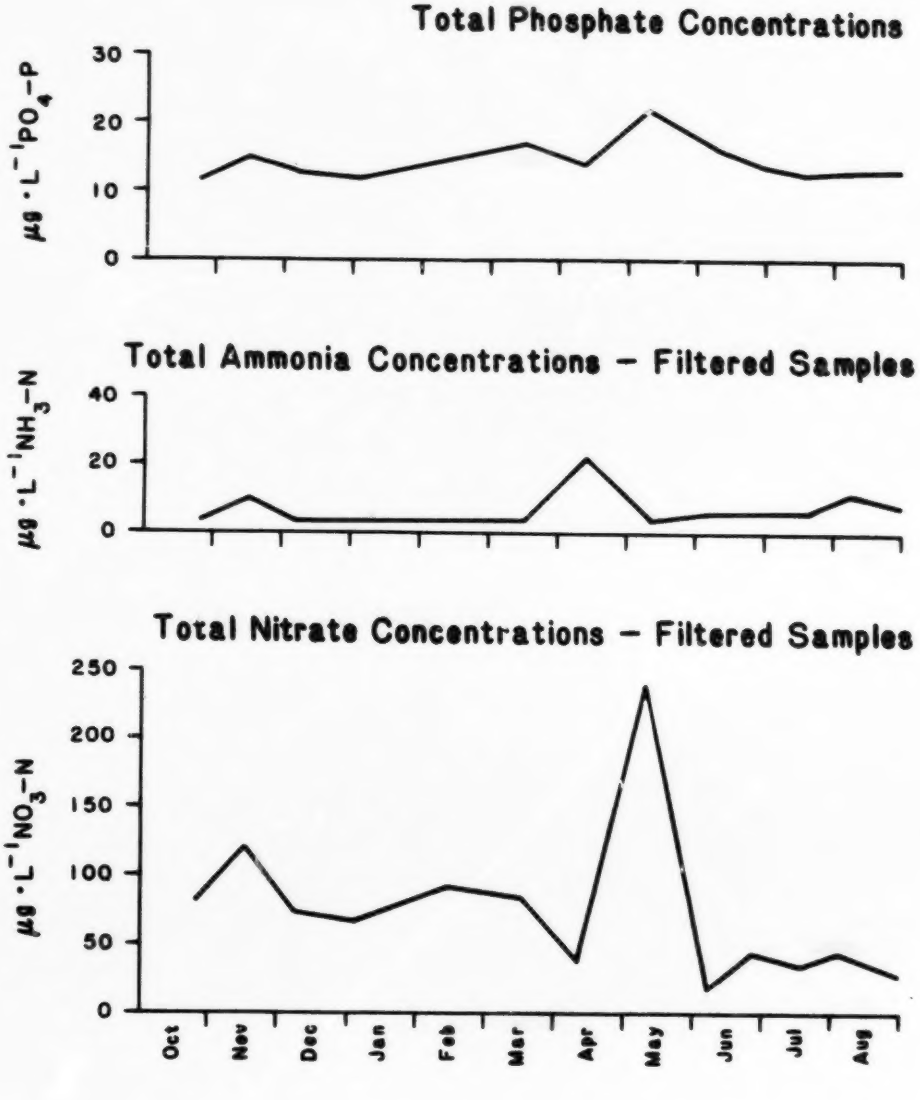
Fig. 53 Nicola River

Diatom Assemblage Size and Composition



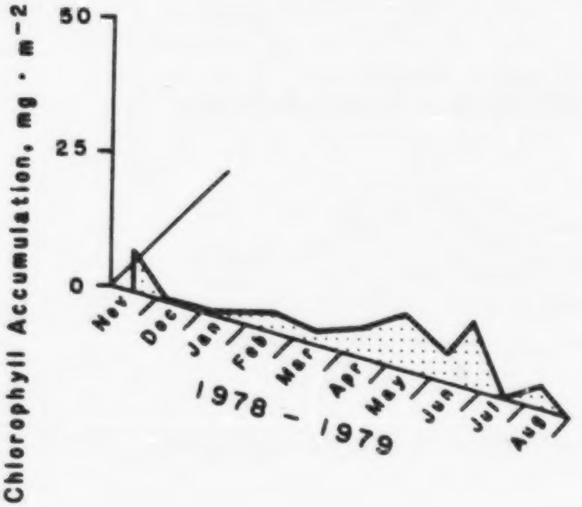
(✦ – sample covered by drift algae)

Fig. 54 Deadman River
Nutrient Concentrations

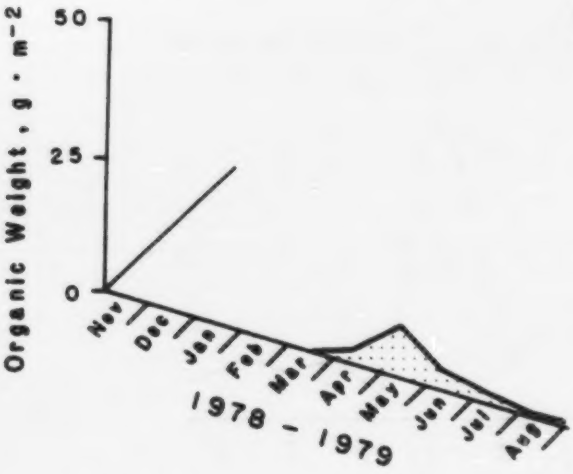


1978 - 1979

Fig. 55(a) Deadman River - Pool Site

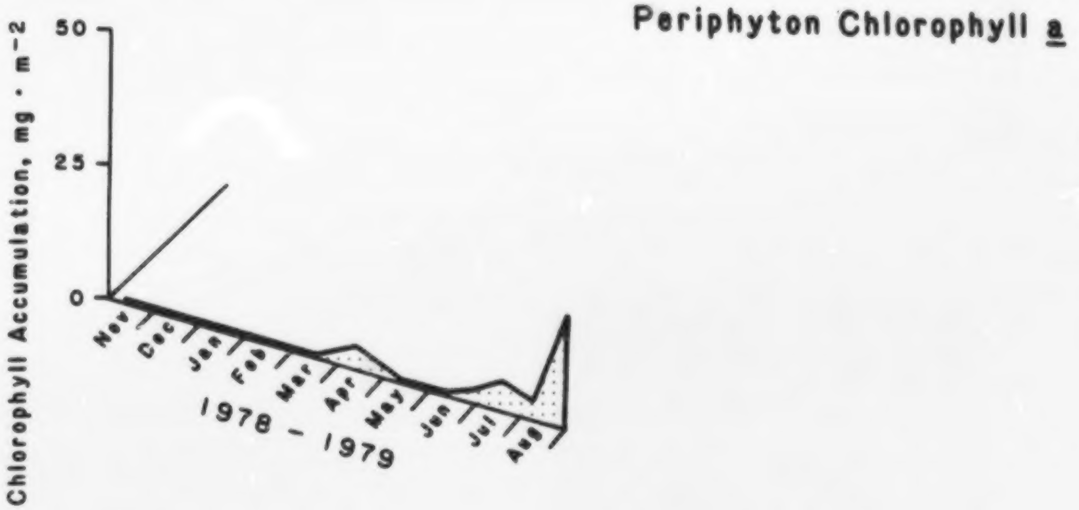


Periphyton Chlorophyll a



Periphyton Organic Weight

Fig. 55(b) Deadman River - Riffle Site



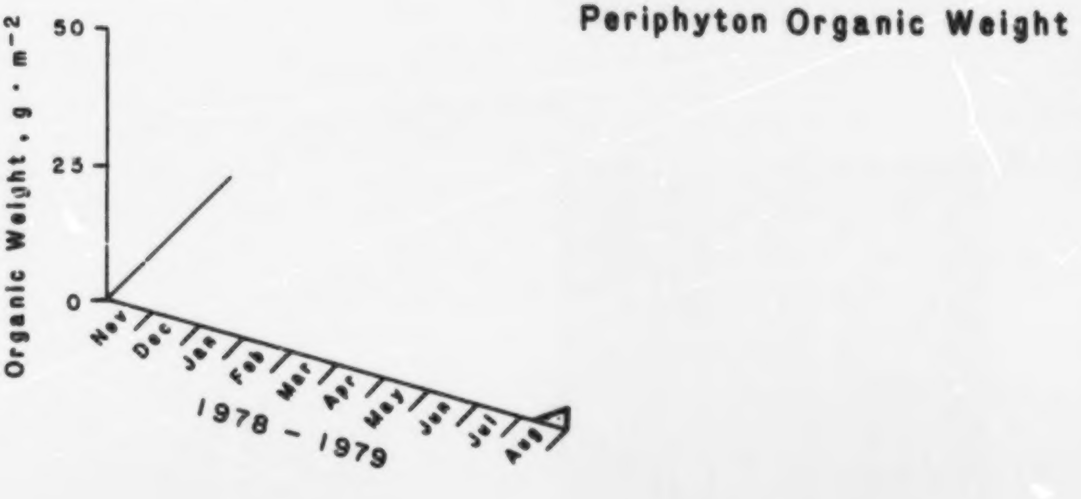


Fig. 56 Deadman River

Periphyton Species Composition, % Abundance

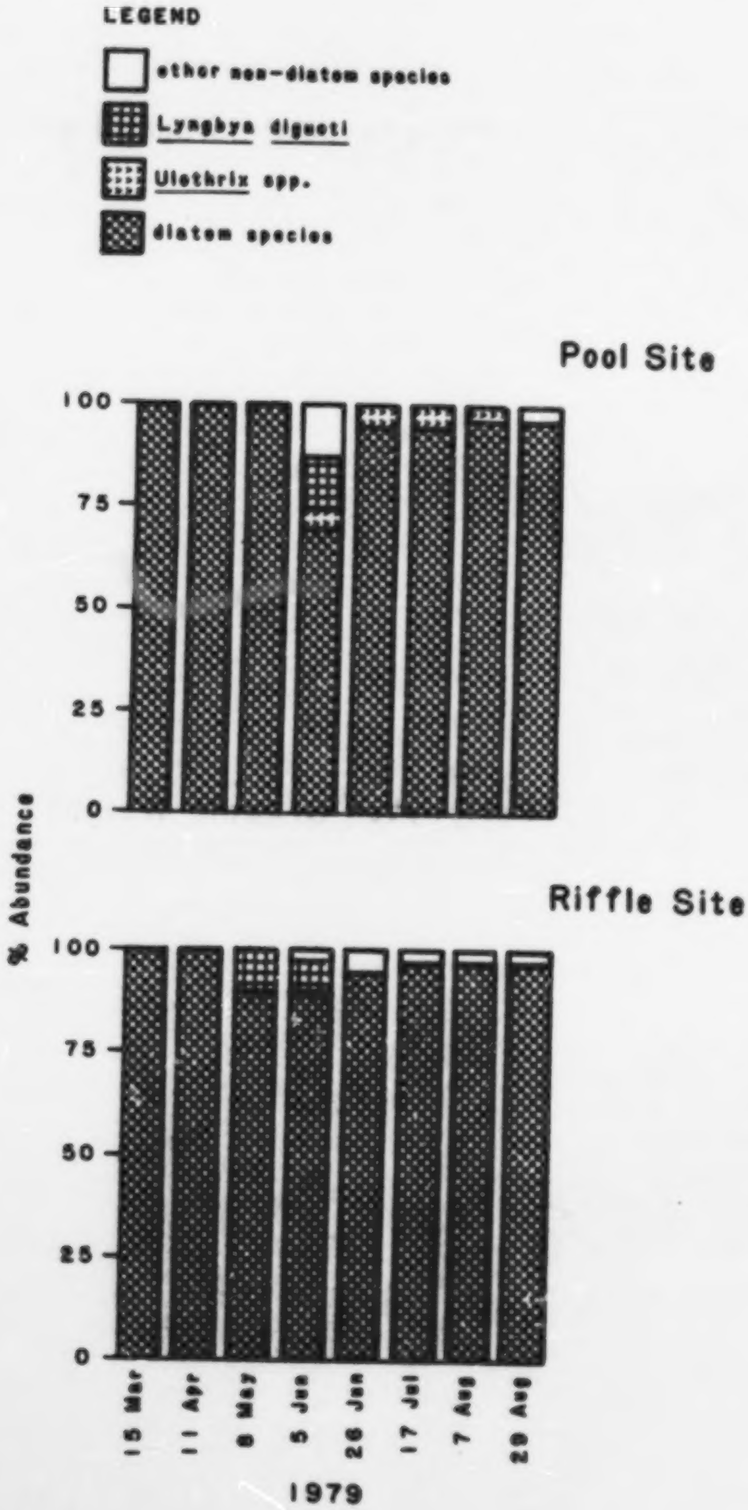


Fig. 57 Deadman River

Diatom Assemblage Size and Composition

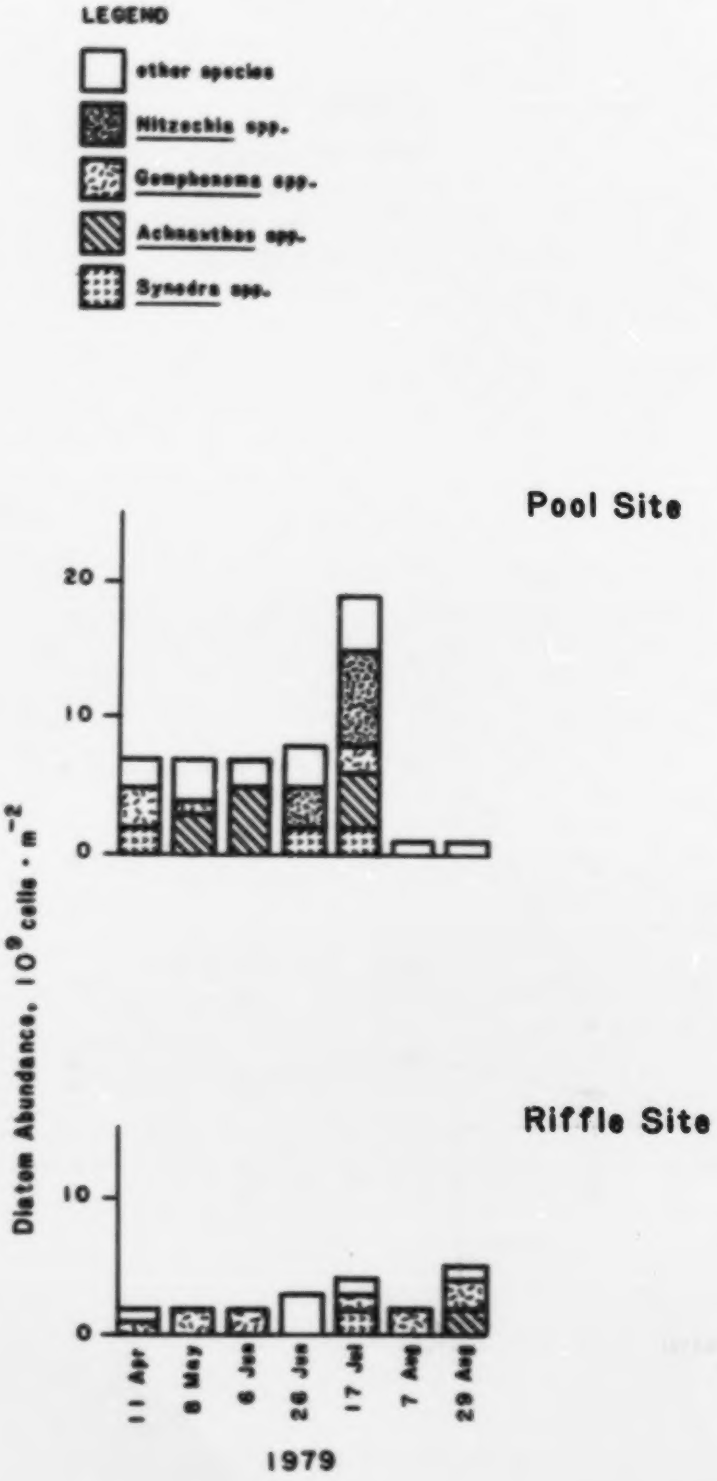


Fig. 58(a) Mean Nutrient Concentrations During The Periphyton Growing Season, 1979 (summer on Quinsam, Qualicum, Capilano, spring on Puntledge)

Total Phosphate

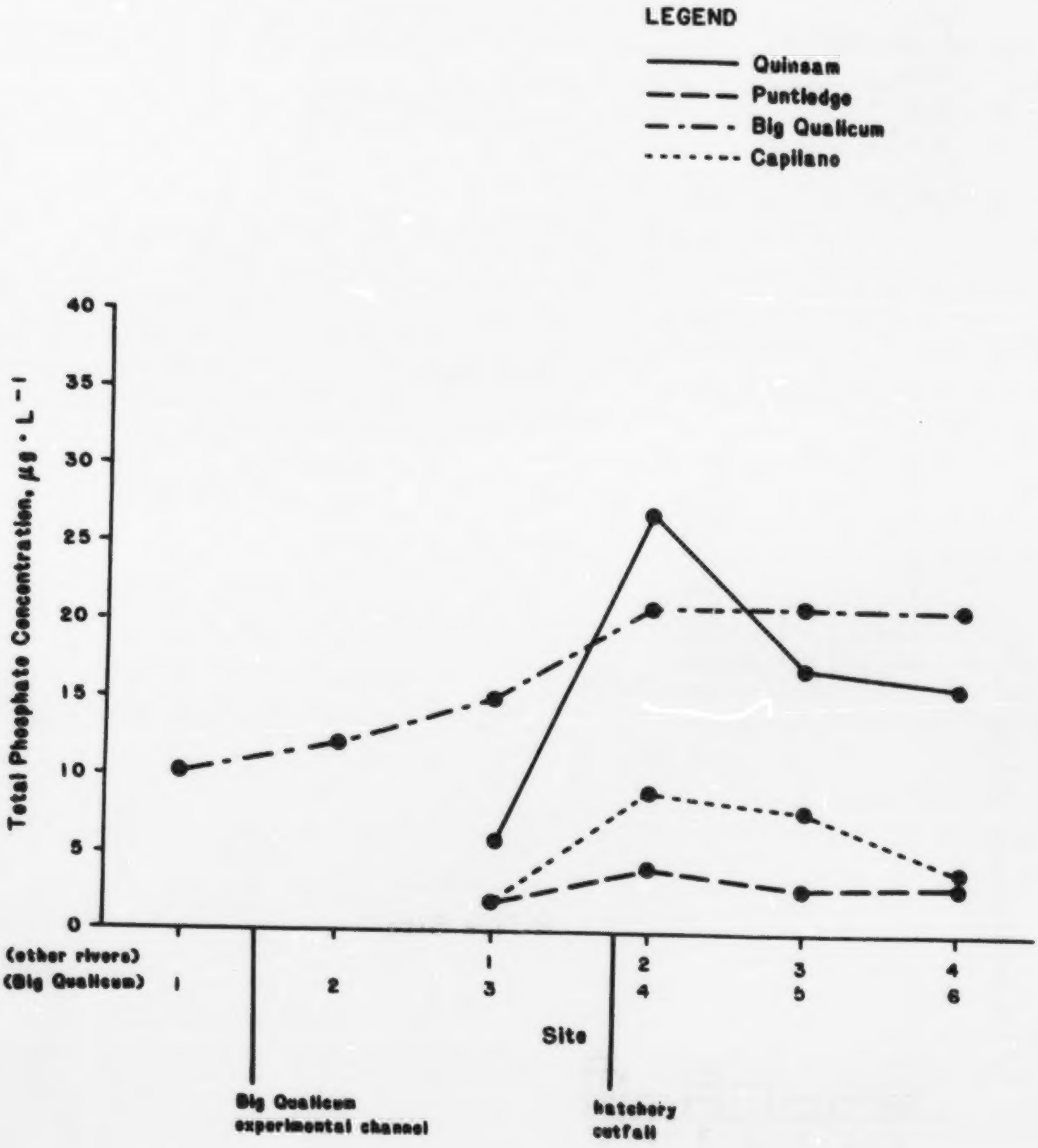


Fig. 58(b) Mean Nutrient Concentrations During The Periphyton Growing Season, 1979 (summer on Quinsam, Qualicum, Capilano, spring on Puntledge)

Ammonia

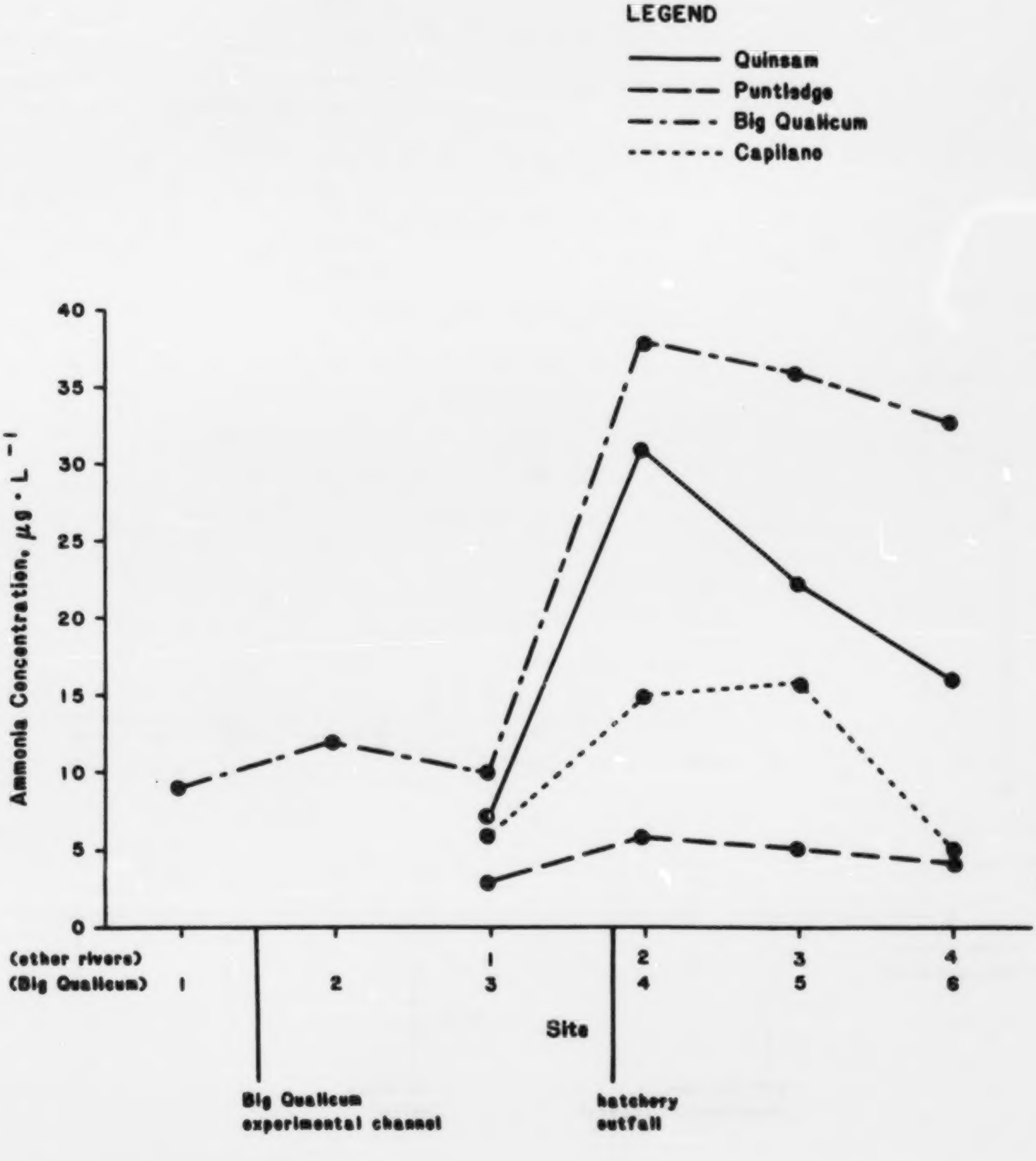


Fig. 58(c) Mean Nutrient Concentrations During The Periphyton Growing Season, 1979 (summer on Quinsam, Qualicum, Capilano, spring on Puntledge)

Nitrate

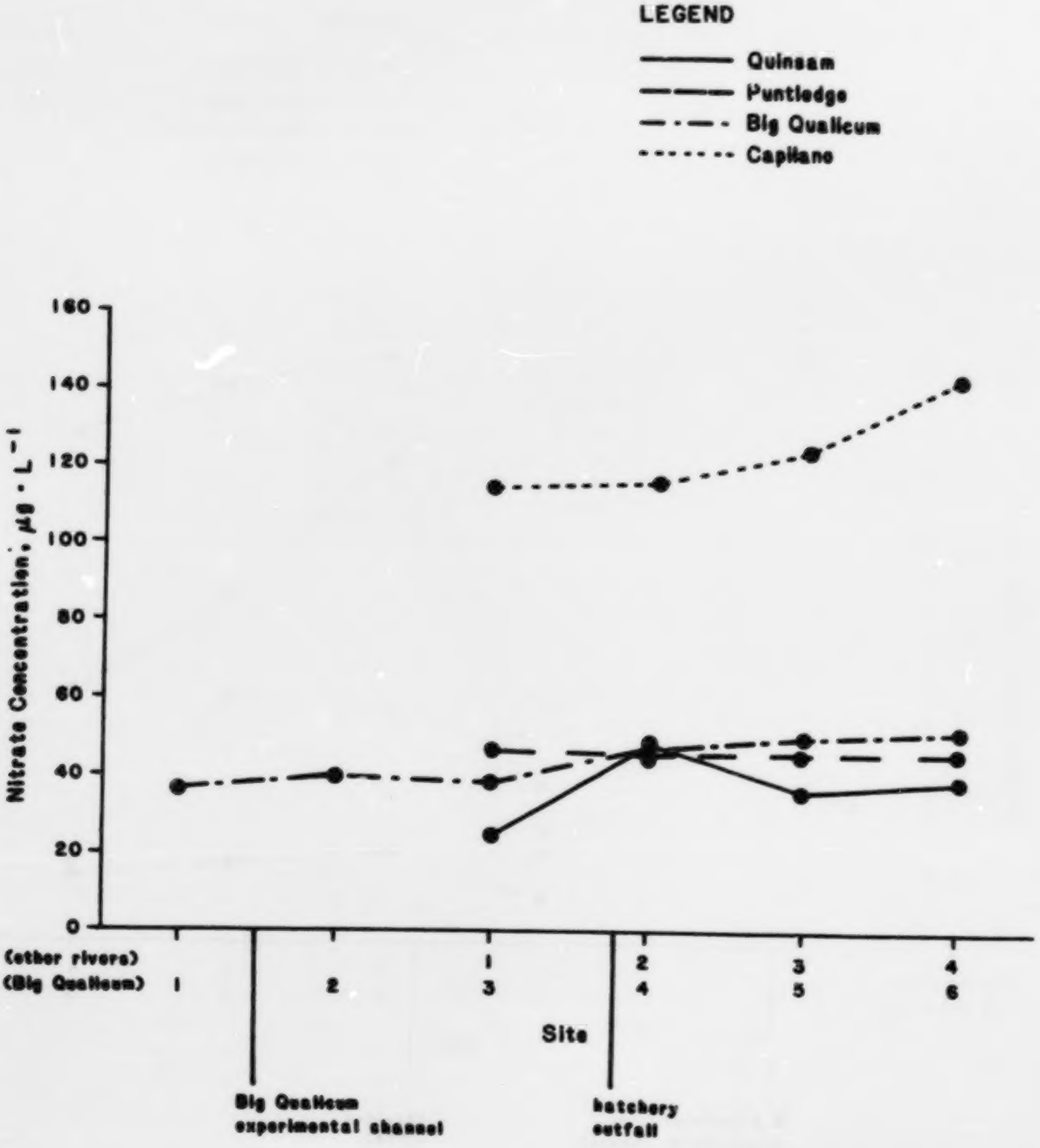


Fig. 59 Hatchery Nutrient Loads

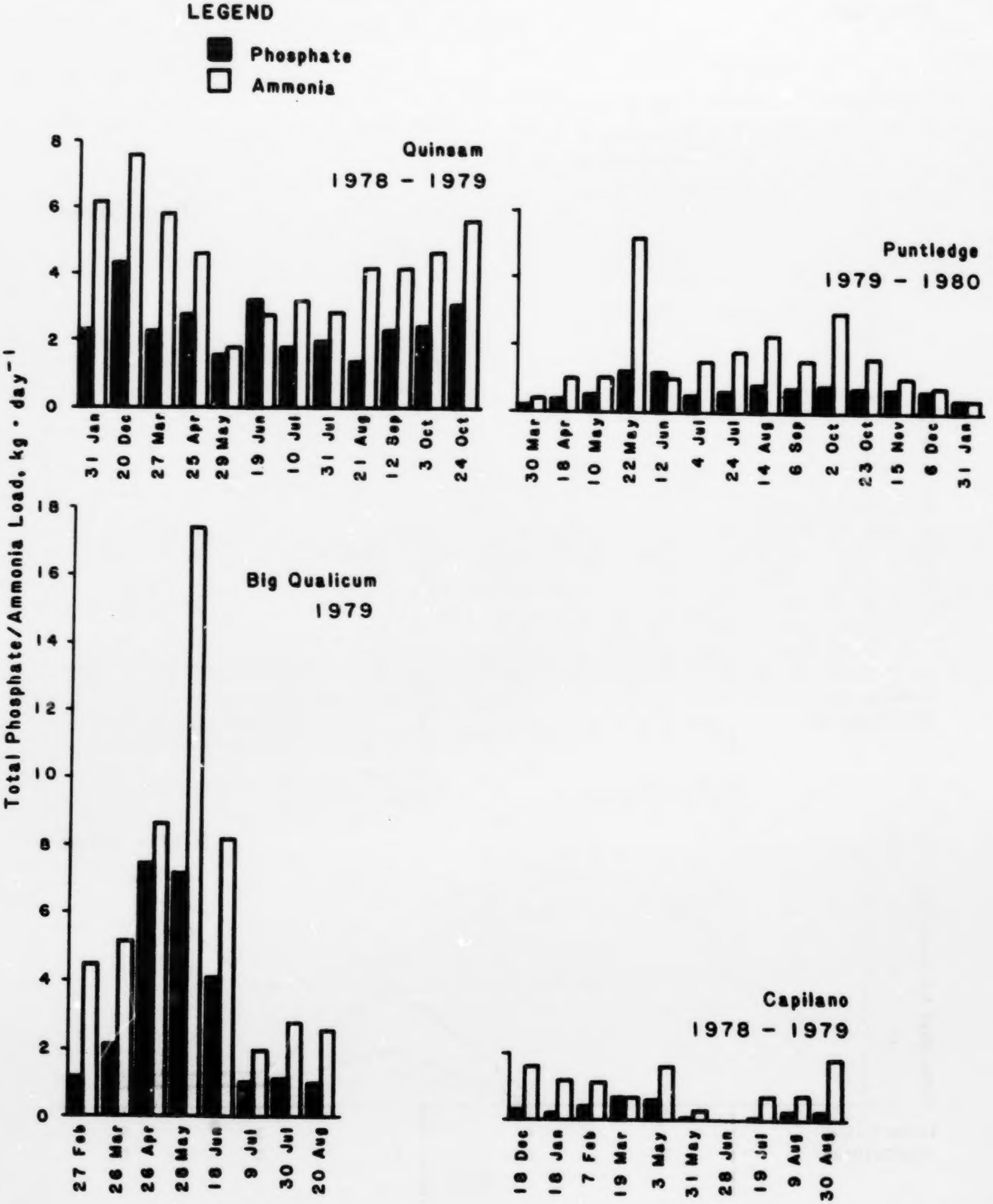


Fig. 60(a) Annual Estimates of Periphyton Accumulation, 1978 - 1979 Chlorophyll a

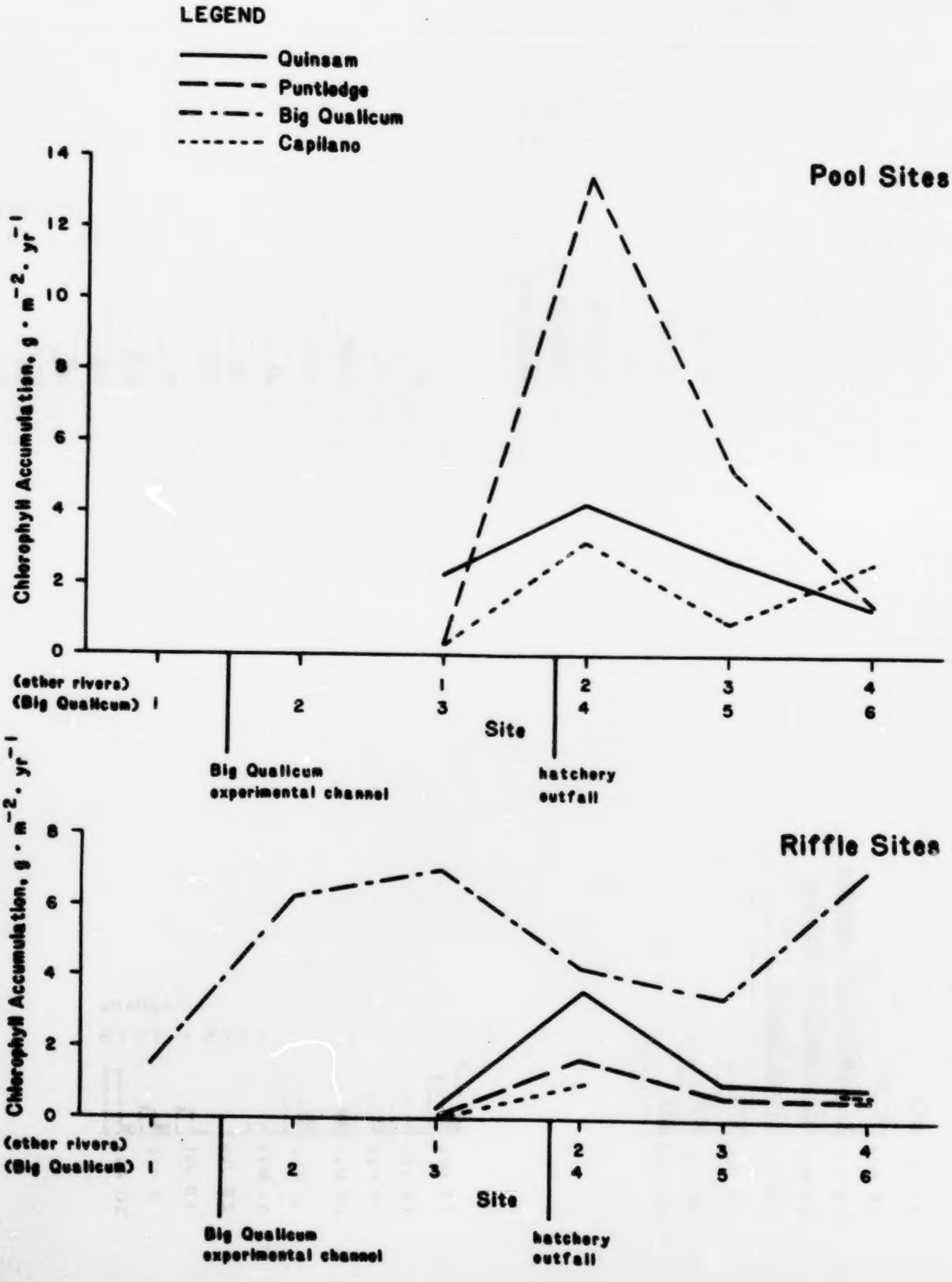
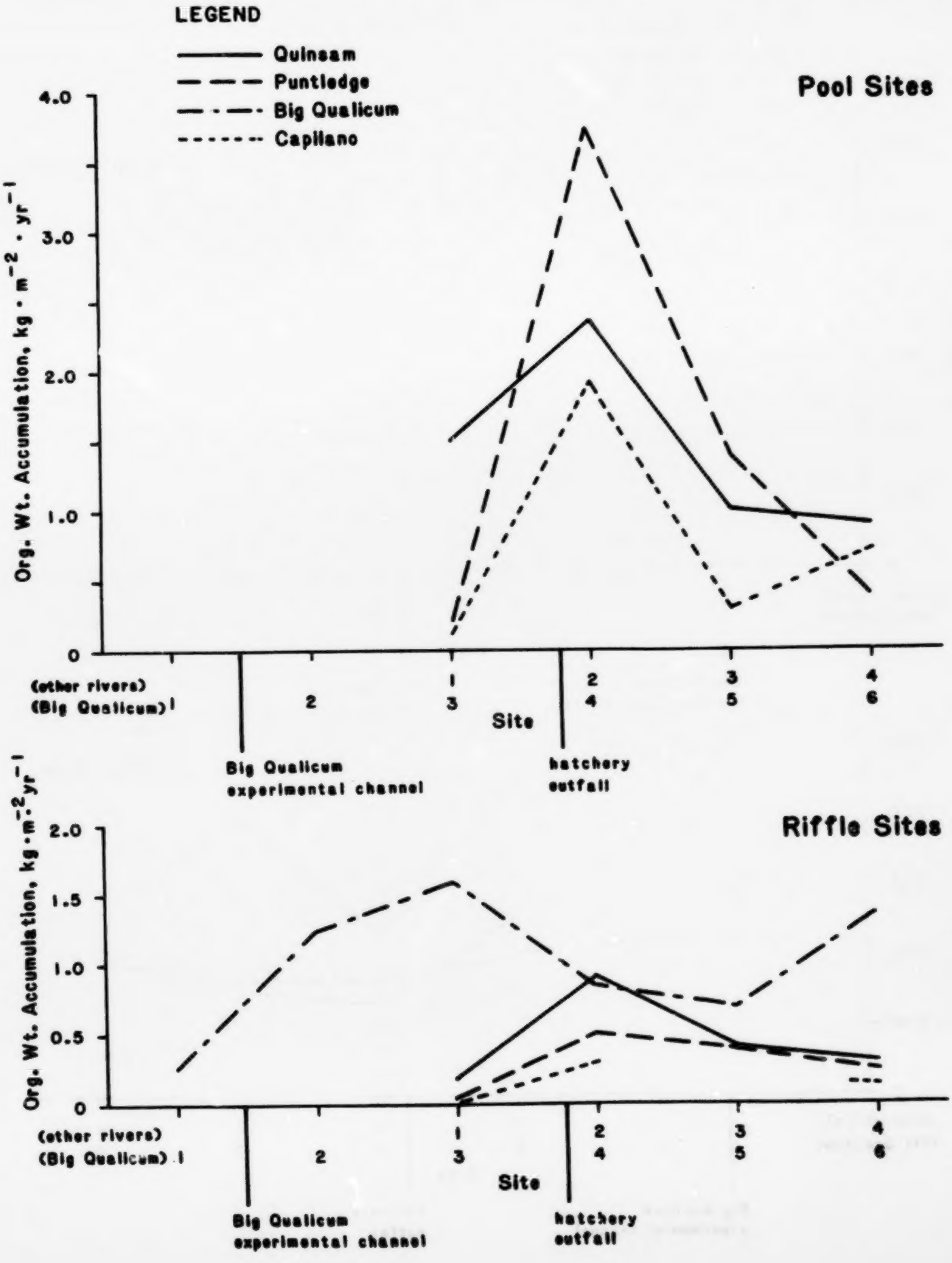


Fig. 60(b) Annual Estimates of Periphyton Accumulation, 1978–1979

Organic Weight



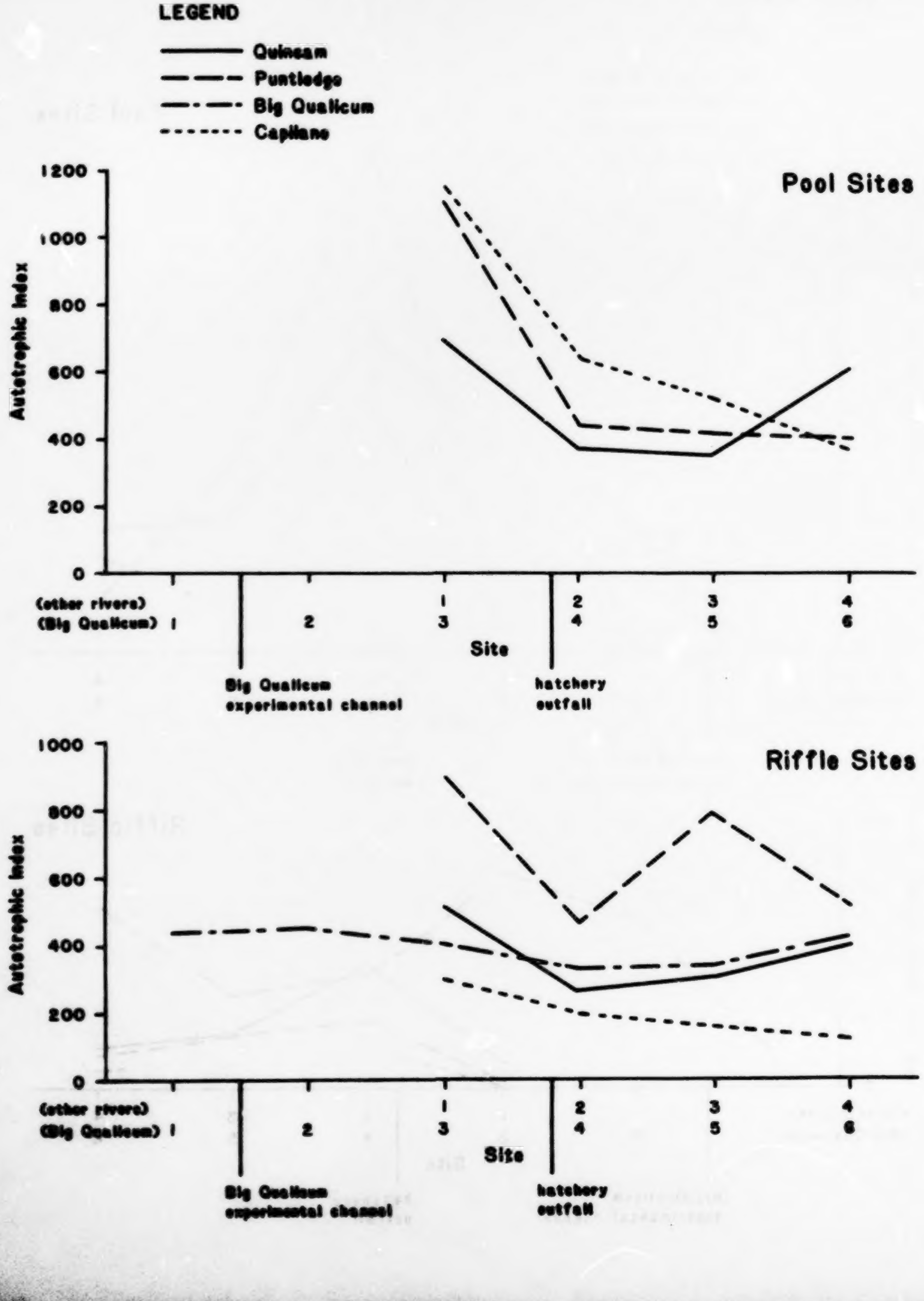
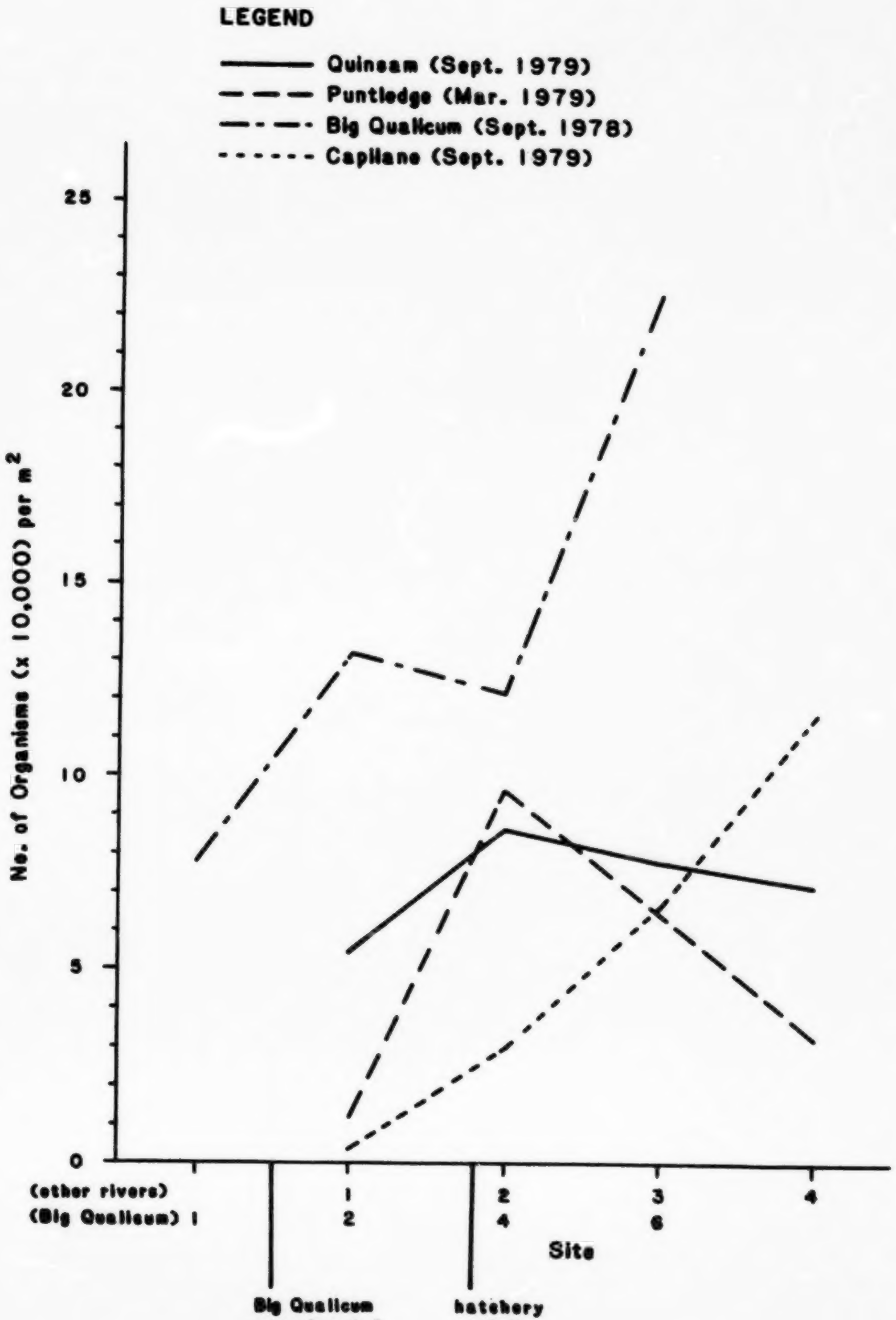


Fig. 61 Autotrophic Index For Periphyton (Ratio of Organic Weight to Chlorophyll a)

Fig. 62 Benthic Invertebrate Numbers During Periods of Maximum Abundance



APPENDIX I

PERIPHYTON SPECIES DISTRIBUTION AMONG THE RIVERS SAMPLED

NOTE:
* = previously unrecorded in British Columbia
. = present
x = common (>5% abundance on at least 5 occasions in major rivers studied, or on the single sampling date in minor rivers)
xx = predominant species at least part of the year (>25% abundance on at least 5 occasions in major rivers studied, or on the single sampling date in minor rivers)

Periphyton were comprised of the following groups. Four hundred species or genera identified (84 new records for B.C.)

29	Cyanophyceae
66	Chlorophyceae
13	Chrysophyceae
273	Bacillariophyceae
5	Xanthophyceae
2	Rhodophyceae
3	Dinophyceae
2	Cryptophyceae
7	miscellaneous (vascular plants, mosses, sewage fungus)

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr
CYANOPHYCEAE						
Anabaena spp.	•	•				
A. circinalis Rabh.						
A. inaequalis (Kuetz.) Born. & Flah.			•			
A. cf. *spiroides*						
A. cf. *variabilis*						
Aphanothece cf. *nidulans*	X	•	XX	•	•	•
Aphanizomenon flos-aquae (L.) Ralfs						
Calothrix spp.	•		•	•		
C. cf. *adscendens*		•				
C. cf. *atricha*						
Chamaesiphon spp.	•	•	XX	•		
Chroococcus spp.		X		•	•	
Coelosphaerium sp.						
Dactylococcopsis cf. *rhapidioides*		•				•
Dichothrix sp.		•				
D. cf. *orsiniana*	•					
Gloeotrichia pisum Thur.		•				
Gomphosphaeria lacustris Chod.	•					
Lyngbya spp.	•		•	•		
L. digueti Gom.	XX	X	XX	X	•	•
L. nordgaardhii Wille	•		•			•
Merismopedia sp.	•	•	•			
Nostoc cf. *pruniforme*						
Oscillatoria spp.					•	•
O. cf. *limosa*				•		
Phormidium spp.	•		•			
P. autumnale (C. A. Ag.) Gom.	X	XX	X	XX	XX	•
Plectonema notatum Schmidle	XX	XX	XX	X	•	X

PERIPHYTON SPECIES DISTRIBUTION

Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Nixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
•											•												
											•												
	•																						
											•												
											•												
•	XX	•	•	•	•					X	X	X		•							•		
												•											
	•	•										•	•										
•						XX					•												
																				•			
•	XX	•								•	•	•					•			•			
X		•	•		•						•	•	•								•		
											•												
•				•																			
•																							
																				•			
•																							
	•	•									•	•											
X	XX	X	•	•	•	X	•			X	XX	X	•	X	•								
	•			•																			
•	•																					•	
					XX																		
			•	•																			
		•									•												
	•					X							•										
XX	X	XX	XX	•	X		•		XX	•	•	•	XX	X	•		•	•			XX		•
XX	XX	X	•	X				•	•	•	•	•								•			

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.
CYANOPHYCEAE					
Stigonema mamillosum (Lyngb.) C. A. Ag.	•	•	•	•	
CHLOROPHYCEAE					
Ankistrodesmus falcatus (Corda) Ralfs	•	•	•	•	
Bambusina spp.	•			•	
Bulbochaete spp.	X	X			
B. cf. furberae				XX	
Characium spp.	•				X
C. cf. rabenhorstii			•		
Chlorella sp.					
Chlorococcum spp.		•	•		
Cladophora sp.		•			
C. glomerata (L.) Kuetz.	•		XX		
Closteriopsis longissima Lemm.	•	•			
Closterium spp.	•	•	•	•	•
Coccomyxa spp.					•
Coelastrum spp.	•	•			
Coleochaete sp.		•			
C. orbicularis Prings.	•				
Cosmarium spp.	•	•	•	•	
Cylindrocystis sp.				•	
Draparnaldia sp.					
D. glomerata (Vauch.) C. A. Ag.	X	X		XX	XX
D. plumosa (Vauch.) C. A. Ag.	•				
Elakotothrix gelatinosa Wille					
Euastrum spp.	•	•		•	
Geminella minor (Naeg.) Heering	•	X	•	XX	•
Gloeocystis spp.		•	•	•	

PERIPHYTON SPECIES DISTRIBUTION

ledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Nixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
	• •	• •		•						•	•	•								•			
	•	XX	X	• •						•	• •		•										
	• XX •		•	•	•	XX				• •	• •	•	•				•						
	•	•	•	•						•	• •	•	•	•								•	
		XX	XX	XX				•		X	XX		•	X									•
	• •	• XX •	•	•	XX					•	• •	•			X								

	Quinsam R.	Puntleuge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr
CHLOROPHYCEAE						
Gloeocystis vesiculosa Naeg.	•					
Gonatozygon sp.				•		
Microspora spp.						
M. amoena (Kuetz.) Rabh.			•			X
M. cf. *loefgrenii*					XX	
Mougeotia spp.	X	X	•	XX	•	•
Nephrocytium spp.	•					
Netrium spp.	•			•		•
Oedogonium spp.	X	XX	•	X	•	•
Oocystis spp.	•	•	•			•
Pediastrum spp.	•	•	•	•		
P. boryanum (Turp.) Meneg.						
Pleurotaenium spp.		•		•		
Protoderma viride Kuetz.						
Rhizoclonium hieroglyphicum (C. A. Ag.) Kuetz.						
R. hookeri Kuetz.						
Scenedesums spp.	•	•		•		•
S. bijuga (Turp.) Lagerh.			•			
Selenastrum spp.	•			•		
Spirogyra spp.	X	XX	•	X	X	•
Spondylosium spp.	•	•	•			
Staurastrum spp.	•	•	•			•
**Stichococcus subtilis* (Kuetz.) Klercker				•		
Stigeoclonium cf. *nanum* Kuetz.						
S. stagnatile (Hazen) Collins	XX	XX	X	X	•	•
Tetraedron spp.	•					
Tetraspora spp.	XX	•	•	•		
T. cylindrica (Wahl.) C. A. Ag.						

PERIPHYTON SPECIES DISTRIBUTION

Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
	•	•	XX	X							•	•	•			XX				•			
X XX	• • •	XX • X	• •	• • • •				•		• •	• • X	• •	X X	•	XX		•	• •		• •	•		
	•	• •			XX						• •												
XX	• •	• • X	X	• •	XX					•	• • • X	XX •	XX		XX		•	XX		•			
X	• • X	• X	•	• •						• • •	• XX	•	• XX	• XX	•		•		•	•			
	•	•			XX				• XX	•	• •												

PERIPHYTON SPECIES DISTRIBUTION

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Nixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
CHLOROPHYCEAE																									
Tetraspora gelatinosa (Vauch.) Desv.			.																						
T. lubrica (Roth) C. A. Ag.						XX																			
Ulothrix sp.																			.						
U. aequalis Kuetz.													.												
U. cylindricum Presc.	.			XX	X						X														
U. subconstricta G. S. West		.					XX								X	.						.			
U. subtilissima Rabh.						X										.									
U. tenerrima Kuetz.	X	X	X	XX								X					.					XX			
U. tenuissima Kuetz.	XX	XX	XX	XX	XX	.	XX			XX		XX	XX	.	XX	X	.		XX		X	X			
U. zonata (Weber & Mohr) Kuetz.	XX	XX	XX	XX	XX	.	XX			XX	XX	XX	XX	X	XX	XX			XX		XX	X		X	
unidentified coccoid green			.	X									.	.											
Westella botryoides (W. West) de Wildem.	.																								
Zygnema spp.	X	.		X	XX							.	.			XX	X		X			X	XX		.
CHRYSOPHYCEAE																									
Bicoeca sp.				.																					
Chrysocapsa spp.	.		.	.																					
Chrysophaera sp.				.																					
Dinobryon sp.			.																						
D. divergens Imhof		.		.																					
D. sertularia Ehrbg.				X																					
D. sociale Ehrbg.				.		.							.	.											
Hydrurus foetidus (Vill.) Trev.	X	XX	.	XX	XX	XX	.		XX		XX	XX	X	.		XX			.						
Kephyrion sp.				.																					
Mallomonas spp.	.	.		.		.								.											
M. pseudocoronata Presc.	.													.											
Ochromonas spp.														X											
Synura spp.				.		.																			

PERIPHYTON SPECIES DISTRIBUTION

	Quinsam R.	Puntleuge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonapart R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
BACILLARIOPHYCEAE																													
Achnanthes spp.	•		•				•																						
Achnanthes sp. (long)					•				•							•													
A. affinis Grun.	X	•	•	X	•	XX	•	X	•	XX	X	•				•	•	•	X	•	•	•	•	•		•	•		•
A. clevei Grun.											•								•		•		•				•	•	•
A. clevei var. rostrata Hust.	•	•	•				•					•				•		•	•	•		•							•
A. exigua Grun.	•	•	•	•			•	•			•						•		•			•							
A. flexella (Kuetz.) Brun	•	•	•		•		•		•		•	•				•	•	•	•	•	•	•		•	•	•	•	•	•
*A. gibberula Grun.	•	•	•	XX	XX	•	•	XX	XX	•			XX			•			•					XX					
A. hauckiana Grun.	•																												
A. hustedtii (Krasske) Reim.				•				•																					
A. lanceolata (Bréb.) Grun.	X	•	X	•	•		X	•	•		XX	•				•	•	X	•	•	•	•	•	•	•	•	•	•	X
*A. lanceolata var. dubia Grun.		•	•				•																						
*A. lemmermannii Hust.	•	•																											
A. lewisiana Patr.												•																	
*A. linearis forma curta H. L. Sm.	•	•	•				•																						
*A. linearis var. pusilla Grun.	XX	X	X	•	X	•	X	•	X	•	•					•	•	•	X	•	•	•	•	•	X	•	•	•	•
A. marginulata Grun.		•	•	•	•	XX	•	•	•	XX	•		•			•	•	•	•	•	•	•	•	•		•		X	•
A. microcephala Kuetz.	•	•	•	•			•	•					•			•			•	•		•	•	•	•		•	•	•
A. minutissima Kuetz.	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	X	X	•	X	XX	XX	XX	XX	XX	XX	X	X	XX	XX	XX	XX	XX	X
A. peragalli Brun & Hérib.																			•										
A. sublaevis var. crassa Reim.			•	•			•	•																					
Amphipleura pellucida Kuetz.	•	•	•	•			•	•			•	•					•	•	•			•	•				•	•	•
Amphora ovalis (Kuetz.) Kuetz.	•	•	•	•	•		•	•	•		•	•				•	•	•	•	•	•	•	•	•		•	•		•
Anomoeoneis serians var. brachysira (Bréb. ex Kuetz.) Hust.				•			•	•					•												•	•			
A. vitrea (Grun.) Ross	•	X	•	•	•	•	•	•	•	•						•	•	•	X	•	•		•	•			•	•	•
Asterionella formosa Hass.	•	•	•	•			•	•									•	•	•				•				•		•
Biddulphia cf. laevis	•		•				•																						
Caloneis spp.	•										X	•											•						

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr
BACILLARIOPHYCEAE						
Caloneis cf. *amphisbaena*						
C. cf. *bacillum*						
C. cf. *limosa*		•				
C. ventricosa var. *minuta* (Grun.) Patr.						
**C. ventricosa* var. *truncatula* (Grun.) Meist.		•		•		
Chaetoceros sp.	•		•			
Cocconeis disculus (Schum.) Cl.	•					
C. pediculus Ehrbg.			•	•		
**C. placentula* var. *euglypta* (Ehrbg.) Cl.	•				•	
C. placentula var. *lineata* (Ehrbg.) V. H.	X	•	X	•	•	•
Cyclotella antiqua W. Sm.		•				
C. bodanica Eulen	•	•	•			
C. glomerate Bachm.	•	•	•	•	•	
C. kuetzingiana Thwaites	•	•	•		•	
C. meneghiniana Kuetz.			•	•		
C. michiginiana Skv.				•		
C. ocellata Pant.	•	•	•	•	•	
C. pseudostelligera Hust.						
C. stelligera Cl. & Grun.	•	•	•	•		
Cymatopleura solea (Bréb.) W. Sm.	•	•	•			
Cymbella spp.		•	•		•	•
**C. acuta* (A. S.) Cl.						
C. affinis Kuetz.			•		•	
**C. angustata* (W. Sm.) Cl.	•	•	•	•	•	
C. cesatii (Rabh.) Grun. ex A. S.	•	•	•	•	•	•
C. cistula (Ehrbg.) Kirchn.	•	•	•	•	X	
C. cuspidata Kuetz.						
C. cymbiformis Ag.	•	•	•			

PERIPHYTON SPECIES DISTRIBUTION

Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Nixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
	•			•						•	•					•						•
• • X	• •	• •	•	• XX XX	• X • XX		•	•	•	• XX	• XX	• •	• •	•	•	•	•	•	• •	•		• •
• • • •	• •	• •		• • •	• • •				• •	• • • •	• •	• •					• •	• •		• •		•
• • •	• • •	•					•		• •	• • •	•	•	•				• •	•		•		• •
• • • •	• •	• • • •	• •	• •	• •				• • • •	X •	• •	• • •	• •	• •	• • • •			• •	• • •	• • •	• • •	• •
• •	•	X		•	•				• •	•	•	• •	•	•	X	•	•	•	•	•	• •	•

	Quisam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	
BACILLARIOPHYCEAE						
*Cymbella cymbiformis var. nonpunctata Font.		•				
C. cf. hauckii				•		
*C. hybrida Grun. ex Cl.	•			•		•
*C. laevis Naeg. ex Kuetz.	•	•	•		XX	
C. lanceolata (Ag.) Ag.		•				
*C. lunata W. Sm.				•		•
C. mexicana (Ehrbg.) Cl.	•	•				
C. microcephala Grun.	•		•	•	•	
C. minuta Hilse ex Rabh.	XX	X	XX	XX	X	•
C. minuta forma latens (Krasske) Reim.				•		
*C. minuta var. silesiaca (Bleisch ex Rabh.) Reim.	X	X	X	•	•	
*C. muelleri Hust.						
C. naviculiformis Auersw. ex Heib.	•	•	•	•	•	
C. prostrata (Berk.) Cl.						
*C. prostrata var. auerswaldii (Rabh.) Reim.			•	•		
*C. proxima Reim.	•					
C. sinuata Greg.	X	•	X		•	
C. tumida (Bréb. ex Kuetz.) V. H.						
C. tumidula Grun. ex A. S.	•		•		•	
Denticula elegans Kuetz.	•	•	•	•	•	
Diatoma hiemale (Roth) Heib.	•					
*D. hiemale var. mesodon (Ehrbg.) Grun.	X	XX	X	X	XX	X
D. tenue Ag.	•	•	•		•	
D. vulgare Bory	X	•	XX	•	•	X
*Diatomella balfouriana Grev.				•		
Didymosphenia geminata (Lyngb.) M. Schmidt		•				
Diploneis spp.						
D. cf. marginestriata		•	•			

PERIPHYTON SPECIES DISTRIBUTION

Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonapart R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
•	• •	XX	•	•	•				• •	•		• •	• •	•	•	•			• •	•		•
• XX	• • XX •	• X	• •	• •	•		•	XX	• X	• X	• X	• •	•	•	• •	•	•	•	• •	•	•	•
X • •	• • •	• •		• • •	• •		•	•	X •	• • •	X • •	• •	• • •	• •	•	• •	•	• •	• •	•	•	•
X • •	•	• • •		• •	• •				• • •	• • •	X	• •	•	•	•	•		•	•	•	•	•
X • XX	X • •	XX • •	XX X	• XX • •	• • XX	• X	X	X X	X • •	• • • X	• •	• X •	• • •	•	• •	• • •	• •	• •	• • •	X		X
•						•	•		•			XX	XX	•	•	•					•	XX • •

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.
BACILLARIOPHYCEAE					
*Diploneis oblongella (Naeg. ex Kuetz.) Ross	•	•	•	•	
*D. oculata (Bréb.) Cl.	•		•		
D. cf. puella	•	•	•		•
*Entomoneis sp.				•	
Epithemia sp.				•	
E. sorex Kuetz.		•			
E. turgida (Ehrbg.) Kuetz.	•	•	•	•	
Eunotia spp.	•	•	•		
E. arcus Ehrbg.	•	•	•	•	
E. arcus var. bidens Grun.	•	•	•	•	•
E. bactriana Ehrbg.					•
E. curvata (Kuetz.) Lagerst.	•	•	•	•	•
E. curvata var. (large)				•	
E. cf. diodon					•
E. elegans Østr.	•	•	•	•	•
E. exigua (Bréb. ex Kuetz.) Rabh.			•	•	
E. fallax A. Cl.		•		•	•
E. flexuosa Bréb. ex Kuetz.				•	
E. incisa W. Sm. ex Greg.	•	•	•	•	•
E. maior (W. Sm.) Rabh.	•				
E. monodon Ehrbg.	•				
*E. naegelii Migula	•	•		•	•
*E. nymanniana Grun.	•			•	
*E. parallela Ehrbg.		•			
*E. pectinalis (O. F. Muell.?) Rabh.	•		•		
E. pectinalis var. minor (Kuetz.) Rabh.	•	•	•	X	•
*E. perpusilla Grun.	•	•	•	•	•
*E. praerupta Ehrbg.				•	

PERIPHYTON SPECIES DISTRIBUTION

Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
•	•	•			•	•																	
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•	•	•	•	XX						•			•		•	•		•		•	•		
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		•																					
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	•						•			•													
•	•	X	•	XX	•		•			•	•	•	•					•		•			
•	•	•	•	•	•					•	•												
		•													•								

	Quinsam R.	Puntleuge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.
BACILLARIOPHYCEAE						
**Eunotia* *rostellata* Hust. ex Patr.				•		
E. tenella (Grun.) Cl.	•		•	•	•	
**E. vanheurckii* var. *intermedia* (Krasske ex Hust.) Patr.	•	•	•	•	•	•
Fragilaria spp.						
**F. bicapitata* A. Mayer.			•			
F. brevistriata Grun.	•		•			
F. capucina Desm.						
**F. capucina* var. *mesolepta* Rabh.	X	X	•	•	•	•
**F. constricta* forma *stricta* (A. Cl.) Hust.						
F. construens (Ehrbg.) Grun.	•	•	X		•	X
**F. construens* var. *pumila* Grun.		•				
F. construens var. *venter* (Ehrbg.) Grun.						
F. crotonensis Kitton	•	X	•			XX
**F. nitzschioides* Grun.	•					
F. pinnata Ehrbg.			•			
**F. pinnata* var. *intercedens* (Grun.) Hust.	X	X	X	XX	•	•
F. vaucheriae (Kuetz.) Peters.						
F. virescens Ralfs			•			
Frustulia rhomboides (Ehrbg.) De T.	•	•	•	•	•	•
Gomphoneis herculeana var. *robusta* (Grun.) Cl.		•	•			
Gomphonema spp.	•		•	•		•
Gomphonema sp. (small)	•		•		X	
G. acuminatum Ehrbg.	•	•	•	•		
**G. acuminatum* var. *clavus* (Bréb.) Grun.		•				
**G. affine* Kuetz.		•		•	•	
G. angustatum (Kuetz.) Rabh.	XX	X	X	XX	X	X
**G. angustatum* var. *sarcophagus* (Greg.) Grun.	•	•				
**G. apicatum* Ehrbg.		•				

PERIPHYTON SPECIES DISTRIBUTION

Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
• • •	• • •	• •	•	•		•			• •	•		• •				•	•		•			
• • X	•	• •	• X	• •	•				• •	• X	• •	• • • X	•	X	XX	•	X	•		X	X	XX X
• •			XX	•	X				•	•	X	X			XX XX	•	•			•		•
X • • •	XX •	• •	• •	XX • XX	• •	•			X •	X • • •	X • •	• X •	X •	X	• •	X •	X •	•	X	X •	• •	X • XX
• • •	• • •	X •	•	• • •		•			• • •	• •	• •	• •		•				•	•	• •	• •	• •
X	XX	X	X	X	•		•	•	X	•	XX	• •	•	•	•	•	•	•	•	•	•	•

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.
BACILLARIOPHYCEAE						
*Gomphonema clevei Fricke	.	.	.	.	.	
G. dichotomum Kuetz.						
G. gracile Ehrbg. emend. V. H.	.	.	.	.	.	
G. cf. instabilis						
G. cf. intricatum						
*G. intricatum var. vibrio (Ehrbg.) Cl.		.	.	.	.	
*G. olivaceoides Hust.					.	
G. olivaceum (Lynbg.) Kuetz.	.	.	.	.		
G. parvulum Kuetz.	X	X	X	.	.	.
G. subclavatum (Grun.) Grun.	.	X	.	.	.	
G. subtile Ehrbg.		.				
*G. subtile var. sagitta (Schum.) Cl.		.				
*G. tergestinum (Grun.) Fricke						
G. truncatum Ehrbg.	X	.	.		.	
G. truncatum var. capitatum (Ehrbg.) Patr.		.		.		
*G. truncatum var. turgidum (Ehrbg.) Patr.		.				
G. ventricosum Greg.						
Gyrosigma spp.		.		.		
G. attenuatum (Kuetz.) Rabh.		.				
*G. obtusatum (Sulliv. & Wormley) Boyer	.		.			
Hannaea arcus (Ehrbg.) Patr.	.	XX	XX	X	XX	.
Mastogloia sp.						
Melosira spp.	.	.	.	.	.	
M. granulata (Ehrbg.) Ralfs				.		
M. italica (Ehrbg.) Kuetz.	.	.	.	.	.	.
M. italica var. tenuissima (Grun.) O. F. Muell.						
M. varians C. A. Ag.	.		.		.	.
Meridion circulare (Grev.) Ag.	.	.	.	.	.	X

PERIPHYTON SPECIES DISTRIBUTION

Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Nixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
•	•	•	•		•					•	•	X	•				•						
					•	•						X	X	•									
•	•	•	•							•			•		•			•	•			•	
										•													
											•		•	•	X					•		•	
•	•	•	•							•			•	•	•					•	•	•	•
			•		•					XX	X	XX	•	X			•						
•	•	•			•	•									•			•	•	•	•		X
X	X	•	•	•	•					X	•	X	•	•	•	•		•				•	
X	•	•	•		•		•			•		•						•	•	•			
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XX	XX	X	XX	•	•		•	XX	X	XX	•	•	X	XX	XX	•	XX		•	X	•	X	•
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•	•	•	•		•						•	•		•	•	•							
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											•	•											
	•		•	•	•	•					•	•					XX						
•	•	•	•	X	X	•				•	•	•		•	•			•	X	•		•	

PERIPHYTON SPECIES DISTRIBUTION

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
BACILLARIOPHYCEAE																													
Navicula spp.	•	•	•	•	•	•	•	•	•	•	•						•	•	•					•					•
N. accomoda Hust.																	•	•											
N. amphibola Cl.																			•										
*N. arvensis Hust.	•	•	•	•	•		•	•	•		X					•	•	•		•		•	•		•			•	•
N. aurora Sov.		•	•				•																						
N. cf. bacillum			•				•																						
*N. biconica Patr.				•				•									•	•											
N. cocconeiformis Greg. ex. Grev.		•	•	•			•	•				•																	
*N. confervacea var. peregrina (W. Sm.) Grun.	•																												
*N. contenta var. biceps (Arn.) V. H.	•	•																											
N. cryptocephala Kuetz. and vars.	•	•	•	•	•		•	•	•		•					•	•	•	•		•	•	•		•		•	•	•
*N. cuspidata (Kuetz.) Kuetz.		•																											
*N. elginensis (Greg.) Ralfs	•																												
N. gastrum (Ehrbg.) Kuetz.	•	•									•						•	•		•									•
N. gottlandica Grun.	•																												
N. cf. grimmei												•																	
*N. hambergii Hust.	•		•	•			•	•								•													
*N. hustedtii Krasske	•											•																	
*N. lanceolata (Ag.) Kuetz.			•				•															•							
*N. latissima Greg.		•																											
*N. pelliculosa (Bréb. ex Kuetz.) Hilse	XX	•	XX	•	•	•	XX	•	•	•	XX	•				•	XX	•	•	•			•						
N. peregrina (Ehrbg.) Kuetz.		•	•				•																						
*N. placentula (Ehrbg.) Kuetz.					•				•																				
N. pseudoscutiformis Hust.	•	•	•				•												•							•			•
N. pupula Kuetz.	•	•	•	•	•		•	•	•		•	•				•	•	•	•	•	•	•	•		•	•	•	•	•
N. pusilla W. Sm.	•	•	•				•									•													
N. radiosa Kuetz.	•	•	•		•		•		•			•				•	•	•	•				•	•	•			•	•
*N. radiosa var. parva Wallace																	•												

PERIPHYTON SPECIES DISTRIBUTION

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
BACILLARIOPHYCEAE																									
Navicula radiosa var. tenella (Bréb. ex Kuetz.) Grun.		•	•	•			X	X					X	X	•	•				•		•			
N. reinhardtii (Grun.) Grun.			•																						
N. rhynchocephala Kuetz.			•																						
N. salinarum var. intermedia (Grun.) Cl.				•			•	•					X	•	•	•									
N. scutelloides W. Sm. Ex Greg.			•																				•		
*N. scutiformis Grun. ex A. S.		•																							
N. cf. secreta var. apiculata							•																		
N. tripunctata (O. F. Muell.) Bory	•			•			X	X					X	•	•	•								•	
N. cf. vanheurckii			•																						
N. viridula (Kuetz.) Kuetz. emend V. H.		•	•	•			X	X				•	•						•						
*N. viridula var. rostellata (Kuetz.?) Cl.					•																				
Nedium spp.	•			•	•		•						•				•		•				•		•
N. affine (Ehrbg.) Pfitz.		•		•																					
*N. affine var. amphirhynchus (Ehrbg.) Cl.				•																					
*N. binode (Ehrbg.) Hust.	•		•	•								•			•		•	•						•	•
N. bisulcatum (Lagerst.) Cl.												•													
N. dubium (Ehrbg.) Cl.	•																								
N. gracile forma aequale Hust.				•																					
N. iridis (Ehrbg.) Cl.																									•
N. iridis var. amphigomphus (Ehrbg.) A. Mayer		•																							
Nitzschia spp.	•	•	•			•			•			•													
Nitzschia sp. (faint)		X		X									•						X						
Nitzschia sp. (sigmoid)				•									•												
N. acicularis W. Sm.	•	•	X	•			•				•	•	•	•	•	•		•		•	•				•
N. dissipata (Kuetz.) Grun.	•	•	•	•	•		X	X				•	•		•	•		•			•			•	•
N. cf. dubia																									
N. cf. fonticola	XX	X	X	•	•		XX	•	X		•	•	XX	•	•	•	•	•	•	•	•	•	•		•
N. heufleuriana Grun.							•																		

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	
BACILLARIOPHYCEAE						
Nitzschia cf. kuetzingiana	•	X	•	•	•	
*N. palea (Kuetz.) W. Sm.	XX	XX	XX	X	•	
N. sigmoidea (Ehrbg.) W. Sm.	•	•	•	•		
N. tryblionella Hantz.	•	•	•	•	•	
Opephora martyi Hérib.	•		•	•		
*Peronia fibula (Bréb. ex Kuetz.) Ross				•		
Pinnularia spp.	•	•	•	•		•
*P. divergens var. parallela (Brun) Patr.				•		
P. gentilis (Donk.) Cl.	•					
*P. latevittata Cl.				•		
P. mesolepta (Ehrbg.) W. Sm.		•				
P. subcapitata Greg.	•	•		•		•
Rhizosolenia longiseta Zach.	•	•	•	•	•	
Rhoicosphenia curvata (Kuetz.) Grun. ex Rabh.	•	•	•	•	•	
Rhopalodia gibba (Ehrbg.) O. Muell.	•	•		•		
Stauroneis spp.	•	•		•		
S. anceps Ehrbg.	•	•	•	•		
*S. anceps forma linearis (Ehrbg.) Hust.			•			
S. fluminea Patr. & Freese				•		
S. kriegeri Patr.			•	•	•	
*S. nana Hust.	•					
S. phoenicenteron forma gracilis (Ehrbg.) Hust.				•		
*S. smithii var. incisa Pant.		•				
Stephanodiscus sp. (small)			•			
Stephanodiscus sp. (large)	•		•			
S. astraea (Ehrbg.) Grun.		•	•	•		
S. astraea var. minutula (Kuetz.) Grun.						
S. hantzschii Grun.				•	•	

PERIPHYTON SPECIES DISTRIBUTION

Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
	•	•	•		XX	XX					XX	X	•	•		•	X	•	X				•
X	XX	X	•	X	XX	XX		X	•	•	•	XX	•	•	•	•	X	X	•	•	•	•	•
	•	•			X	•				•	•	•	•			•	•		•				•
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		•	•		•	•				•	X	X	•										

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	
BACILLARIOPHYCEAE						
Stephanodiscus niagare Ehrbg.						
Surirella spp.						
*S. angustata Kuetz.		•				
S. ovata Kuetz	•	•	•	•		
*S. ovata var. minuta Bréb.		•		•		
Synedra spp.						
S. acus Kuetz.	•					
*S. amphicephala Kuetz.					•	
*S. cyclopum Brutschy.				•		
S. delicatissima W. Sm.	•	X	•	•	•	
*S. demerarae Grun.	•					
*S. incisa Boyer				•		
S. mazamaensis Sov.	•					
*S. parasitica (W. Sm.) Hust.			•			
S. rumpens Kuetz.	XX	XX	X	XX	XX	X
*S. rumpens var. fragilarioides Grun.	•	•		•	•	
*S. socia Wallace	•					
S. ulna (Nitz.) Ehrbg. and vars.	XX	X	X	•	X	•
Tabellaria fenestrata (Lyngby.) Kuetz.	X	XX	•	•	•	•
T. flocculosa (Roth) Kuetz.	X	•	•	XX	•	X
Tetracyclus lacustris Ralfs						
XANTHOPHYCEAE						
Tribonema spp.						
T. cf. minus			•			
T. cf. utriculosum			•			XX
Vaucheria spp.	X			•	•	•
V. cf. orthocarpa			•			

PERIPHYTON SPECIES DISTRIBUTION

Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.	Inches Cr.	Loon Cr.	Bonaparte R.	Hixon Cr.	Birkenhead R.	Snootli Cr.	Chilliwack R.	Nicola R.	Deadman Cr.	Eagle R.	Crazy Cr.	Finn Cr.	Bowron R.	Cheakamus R.	Chehalis R.	Little Qualicum R.	Nitinat R.	Quesnel R.	Raft R.	Stuart R.
											•	•											
													•										
	•	•		•	•	•					•	•					•	•	•				•
		•			•	•					X	•					•						
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		•																					
												•											
X	•	•	•							X	•	•	•	•				•	•	•	•	•	•
		•																					
					X					•	•						•						
	•																						
XX	X	XX	XX	X	•	•	•		•	X	XX	XX	X	X	X	•	•	X	XX	X	X	XX	X
		•	•							X			•	•				•		•			
	X	•	X	•	X	X	•	X	•	XX	•	X	X	•	•	•	•	•	X	XX	•	X	•
X	•	•	•	•	•	•			•	•	•	X	•	•	•	•		•	•	•	•		•
	•	XX	•	X	•		•			•	•	•	•	•	•			•	•	•		•	
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	•																						
	•			XX																			
		•	•	•		XX		X	•														
	•																						

	Quinsam R.	Puntledge R.	Big Qualicum R.	Capilano R.	Conuma R.
RHODOPHYCEAE					
Audouinella violacea (Kuetz.) Hamel.	•	•	•	X	
Batrachospermum spp.					
DINOPHYCEAE					
Ceratium hirudinella (O. F. Muell.) Bergh.					
Peridinium spp.	•	•		•	
P. willei Huit.-Kaas			•		
CRYPTOPHYCEAE					
Cryptomonas spp.		•	•	X	
Rhodomonas spp.			•	•	
MISCELLANEOUS					
Callitriche palustris L. (aquatic vascular plant)		X			
mosses	•	•	XX	•	
Nitella sp. (Charophyceae, Chlorophyta)		X			
Potamogeton spp. (aquatic vascular plant)	•				
Ranunculus sp. (aquatic vascular plant)					
Ranunculus aquatilis L. (aquatic vascular plant)		X	X		
Sphaerotilus natans Kuetz. ("sewage fungus")	X	•	X	•	
total number of species identified on each river	199	192	186	185	110

PERIPHYTON SPECIES DISTRIBUTION

	192	• X X	• X	• •	•	Puntledge R.
	186	X X	XX •	• •	•	Big Qualicum R.
	185	•	• •	X •	X	Capilano R.
	110					Conuma R.
	82	X		•	X	Inches Cr.
	113	X XX	XX		XX	Loon Cr.
	69				X	Bonaparte R.
	26				•	Hixon Cr.
	18					Birkenhead R.
	23				•	Snootli Cr.
	125			•	•	Chilliwack R.
	158			•	• •	Nicola R.
	118			• •	• • •	Deadman Cr.
	121	XX			XX	Eagle R.
	74				X	Crazy Cr.
	57				X	Finn Cr.
	52					Bowron R.
	64				X	Cheakamus R.
	60					Little Qualicum R
	47					Nitinat R.
	66					Quesnel R.
	52				X	Raft R.
	47					Stuart R.
	69					

APPENDIX II

BENTHIC INVERTEBRATE SPECIES DISTRIBUTION AMONG THE RIVERS SAMPLED

NOTE: . = present

BENTHIC INVERTEBRATE SPECIES DISTRIBUTION

	Quinsam	Puntledge	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
EPHEMEROPTERA								
Baetidae								
Baetis sp.	•	•	•	•	•	•	•	•
Centroptilum sp.	•	•	•	•	•	•	•	
Pseudocloeon sp.	•	•	•	•	•	•	•	•
Ephemerellidae								
Ephemerella sp.						•	•	
E. doddsi Needham								•
E. (*Caudatella*) sp.						•		
E. inermis Eaton	•	•	•	•	•	•	•	
E. spinifera Needham	•	•	•			•		
unidentified genera	•							
Heptageniidae								
Cinygmula sp.	•	•	•	•	•	•	•	
Epeorus (*Iron*) *longimanus* Eaton	•	•	•		•	•	•	•
Rhithrogena sp.	•		•			•	•	
R. hageni Eaton	•	•	•			•		•
unidentified genera	•	•	•	•	•	•	•	•
Leptophlebiidae								
Paraleptophlebia sp.	•	•	•	•	•	•	•	
Siphlonuridae								
Ameletus sp.	•	•	•		•			
unidentified genera						•		
PLECOPTERA								
Chloroperlidae								
Alloperla sp.						•		
Hastaperla sp.	•		•		•		•	
unidentified genera	•	•	•	•	•	•	•	•
Nemouridae								
Nemoura sp.						•		
unidentified genera	•	•	•	•	•	•		
Perlidae								
Acroneuria sp.						•		
unidentified genera	•	•	•			•		

BENTHIC INVERTEBRATE SPECIES DISTRIBUTION

	Quinsam	Puntledge	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
PLECOPTERA								
Perlodidae								
unidentified genera	•	•	•			•	•	
Pteronarcidae								
Pteronarcella sp.						•		
Pteronarcys sp.						•		
TRICHOPTERA								
Brachycentridae								
Amiocentrus sp.	•		•					
Brachycentrus sp.								•
Micrasema sp.	•							
Glossosomatidae								
Anagapetus sp.	•		•			•	•	
Glossosoma sp.	•		•			•		
Hydropsychidae								
Arctopsyche sp.						•		•
Cheumatopsyche sp.	•	•						
Hydropsyche sp.	•	•	•			•	•	
unidentified genera		•						
Hydroptilidae								
Hydroptila sp.	•	•						
Neotrichia sp.		•						
Oxyethira sp.		•						
Lepidostomatidae								
Lepidostoma sp.	•	•	•	•	•		•	•
Leptoceridae								
Ceraclea sp.		•						
Mystacides sp.	•	•						
Parapsyche sp.						•		

BENTHIC INVERTEBRATE SPECIES DISTRIBUTION

	Quinsam	Puntledge	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
TRICHOPTERA								
Limnephilidae								
Apatania sp.			•					
Discosmoecus sp.		•	•					
Neophylax sp.		•	•					
Onocosmoecus sp.		•			•			
unidentified genera	•	•	•	•	•	•		
Polycentropodidae								
Neureclipsis sp.		•		•				
Polycentropus sp.	•	•		•				
Rhyacophilidae								
Rhyacophila sp.	•	•	•			•		
Wormaldia sp.		•						
DIPTERA								
Blepharoceridae								
unidentified genera	•							
Ceratopogonidae								
unidentified genera	•	•	•		•	•	•	
Chironomidae								
Chironominae								
Cladopelma sp.	•	•						
Cryptochironomus sp.	•	•						
Demicryptochironomus sp.		•						
Endochironomus sp.	•	•	•					
Micropsectra sp.	•	•	•	•	•	•	•	•
Microtendipes sp.	•	•					•	
Paracladopelma sp.	•							
Paratanytarsus sp.			•					
Paratendipes sp.	•	•	•					
Phaenopsectra (Phaenopsectra) sp.	•	•	•					
Phaenopsectra (Tribolos) sp.	•		•					

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	Quinsam	Puntlege	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
DIPTERA								
Chironomidae								
Chironominae								
Polypedilum sp.	•	•	•	•	•	•		•
Rheotanytarsus sp.	•	•	•	•	•	•	•	•
Stempellina sp.	•							•
Stempellinella sp.	•	•	•		•	•	•	•
Tanytarsus sp.	•	•	•					
Orthocladiinae								
Brillia sp.			•		•		•	•
Corynoneura sp.	•	•	•	•	•	•	•	•
Cricotopus sp.	•	•	•	•	•	•	•	•
Eukiefferiella sp.	•	•	•	•	•	•	•	•
Eurycnemus sp.	•		•					
Heterotrissocladius sp.						•		•
Nanocladius sp.		•	•	•	•	•	•	•
Orthocladius sp.	•	•			•			
Paraphenocladius sp.			•					
Psectrocladius sp.	•	•	•	•				
Rheocricotopus sp.	•	•	•		•	•	•	•
Synorthocladius sp.	•	•	•	•	•		•	•
Thienemanniella sp.	•	•	•	•	•	•		•
Prodiamesinae								
Diamesa sp.						•		
Monodiamesa sp.	•	•	•	•	•			
Tanypodinae								
Ablabesmyia sp.	•	•	•					
Derotanypus sp.			•					
Labrundinia sp.	•	•						
Larsia sp.	•	•						
Natarsia sp.	•		•	•	•	•	•	•
Nilotanypus sp.		•						
Paramerina sp.	•	•	•	•	•			
Potthasia sp.	•	•				•	•	
Procladius sp.	•		•					
unidentified genera	•	•	•	•	•	•	•	

BENTHIC INVERTEBRATE SPECIES DISTRIBUTION

	Quinsam	Puntledge	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
Dolichopodidae								
unidentified genera	•	•	•	•	•	•		
Psychodidae								
unidentified genera	•							
Simuliidae								
unidentified genera	•	•	•	•	•	•		
Tabanidae								
unidentified genera	•		•					
Tipulidae								
unidentified genera	•	•	•	•	•	•	•	•
OLIGOCHAETA								
Enchytraeidae								
unidentified genera	•	•	•					
Lumbriculidae								
unidentified genera	•	•	•					
Naididae								
Nais sp.	•	•	•					
N. communis Piguet	•	•	•					
N. elinguis O. F. Mueller	•	•	•					
N. pseudobtusa Piguet	•	•	•					
Pristina sp.	•		•					
P. cf. *foreli*	•							
P. osborni Walton	•		•					
Vejdovskyella comata (Vejdovsky)		•	•					
unidentified genera	•	•	•					
Tubificidae								
Limnodrilus hoffmeisteri Claparede	•	•						
unidentified genera	•	•	•					
Ryacodrilinae								
unidentified genera	•	•						
unidentified families	•	•	•	•	•	•	•	•

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	Quinsam	Puntlege	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
COPEPODA								
Harpacticoida								
unidentified genera	●	●	●	●	●	●	●	
Cyclopoida								
Cyclops sp.			●		●			
C. bicuspidatus thomasi S.A.Forbes		●	●		●			
C. vernalis Fischer			●	●	●			
Eucyclops agilis Koch	●		●					
E. prionophorus Kiefer			●					
Macrocyclops albidus Jurine	●		●		●			
Paracyclops fimbriatus poppei Rehberg	●	●	●		●			
unidentified genera	●	●	●	●	●			
CLADOCERA								
Chydoridae								
Acroperus harpae Baird	●	●						
Alona sp.	●	●	●					
A. affinis (Leydig)	●	●	●					
A. costata Sars			●					
A. quadrangularis O. F. Mueller	●	●	●	●				
A. rectangula Sars	●	●	●					
Chydorus sp.	●	●	●	●	●			
Pleuroxus denticulatus Birge	●	●	●					
P. hastatus Sars	●	●	●					
Macrothricidae								
Ilyocryptus sordidus (Lieven)			●					
AMPHIPODA								
Corophium sp.		●						
Hyalella azteca (Saussure)	●	●						
BIVALVIA								
Margartifera sp.	●							
Pisidium sp.	●	●				●		
Sphaerium sp.	●							
unidenfied genera		●	●					

BENTHIC INVERTEBRATE SPECIES DISTRIBUTION

	Quinsam	Puntledge	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
BRANCHIURA								
unidentified genera			●					
COELENTERATA								
Hydra sp.	●	●	●	●		●		
COLEOPTERA								
unidentified genera	●	●	●		●	●		●
COLLEMBOLA								
unidentified genera	●	●	●		●	●		
GASTROPODA								
Physa sp.	●	●	●			●		
HIRUDINEA								
unidentified genera	●	●	●					
HOMOPTERA								
unidentified genera		●						
HYDRACARINA								
unidentified genera	●	●	●	●	●	●	●	●
ISOPODA								
unidentified genera			●					
NEMATODA								
unidentified genera	●	●	●	●	●	●		●
OSTRACODA								
unidentified genera	●	●	●	●	●	●	●	●
PLANORBIDAE								
unidentified genera	●	●	●	●		●	●	
TARDIGRADA								
unidentified genera	●	●	●		●			

BENTHIC INVERTEBRATE SPECIES DISTRIBUTION

	Quinsam	Puntledge	Big Qualicum	Capilano	Conuma	Loon	Eagle	Finn
THYSANOPTERA								
unidentified genera	•	•			•			
TURBELLARIA								
unidentified genera		•	•		•	•		